

The WHAT'S NEW magazine

MARCH 1989

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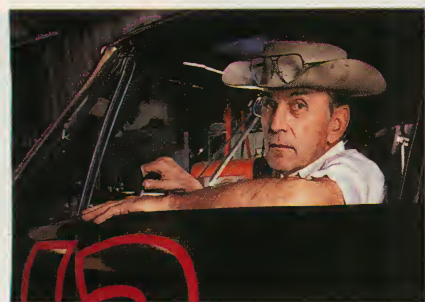
Micromotors

Engineers are taking microchip-building technology and changing the objective: Instead of devices that just shift electrons, they're making microscopic objects designed to move. Tiny motors, mass-produced with other mechanisms on silicon wafers, promise a revolution: with micromachines supplying "muscle" and microelectronic circuits providing "brains." **Page 88**



On base in space

In about seven years the drama of Americans living and working in space will become a reality. And the U.S. space station they will inhabit will be the largest structure ever put into orbit. **Page 94**



Say, Smokey

Twenty-five years ago Smokey Yunick began offering our readers advice on curing ailing vehicles. To mark his anniversary, we asked the veteran race mechanic how the automobile—past, present, and future—looks to him. **Page 105**



Fast-track sedans

European sport sedans have had to make way for American and Japanese challengers. POPULAR SCIENCE tests them to find the best combination of power and comfort. **Page 28**

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COVER PHOTOS BY JOHN B. CARNETT

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Readers Talk Back

Workshop or wife

I have been reading POPULAR SCIENCE for 50 years and the January article "3 Workbenches as Furniture" is undoubtedly the most impractical project I've ever seen. I work on wood, metal, and electronics in my basement, and my wife has been sweeping up after me for 37 years. If I put a workbench with a table saw and belt and disc sander in the living room, I would get to start on only one project: my coffin. Other than the above, I still like the magazine.

Melvon G. Hart, Des Peres, Mo.

The January "3 Workbenches as Furniture" comprises three very fine articles. But one problem is left unanswered: What do you tell your wife when she screams, "Sawdust all over my carpet!" or "Steel shavings all over my carpet!"?

Paul Funderburg, Asheville, N.C.

Under 5 in 20

In December 1988's "The Best of What's New" Tecumseh takes the credit for having the first American-made under-5-horsepower OHV engine, but it is mistaken. In the 1920s and '30s Briggs & Stratton made a one-hp four-cycle one-cylinder upright engine that had a crude but operational kick-starter assembly. This small engine was used on my parent's double wooden tub washing machine. After the power lines began to reach out to the small farms, that engine became our air compressor, driven by a 1/4-hp electric motor.

George Boedeker, Laramie, Wyo.

Subaru support

Your December 1988 article "Wet Set" seems unfairly prejudiced against the Subaru XT6. Statements like "it seems to trip over its front feet—a trait it shares with other Subarus," and "the intriguing engineering of the car is detracted by a video-parlor interior" are unwarranted. For one, the digital dashboard is now gone. The authors of this article assume that Subaru designed its four-wheel-drive cars "to solve traction problems stemming from high

horsepower." That was not the company's intention. The XT6 was made as a sport coupe that would be a good snow and all-season car that just happens to be a decent performance car—not a sports car. At more than \$5,000 less than the next lowest priced competitor, the XT6 is a definite bargain.

David D. Chin, Aurora, Colo.

Less now, more later?

I feel compelled to respond to Ed Warnick's letter about imported automobile components [Jan.]. He states that such components are less expensive, resulting in lower car prices for American consumers, and often reduced delivery time and better-quality cars. The trade deficit is horrendous—and will continue to grow unless we become competitive on the world market. Only by lowering labor costs can we cut the price of our products. It's far better to sacrifice and accept less now and retain future job security than to lose all income later, when jobs are abolished because of a limited market for our over-priced products.

Thomas Murray
Columbia, S.C.

Essentially not banned

The January article "The Man Who Knew Too Much" was very good, but it contained one key error. Aerosol use of CFCs (chlorofluorocarbons) was limited in the United States—not banned as you state. A category of use called "sterilants" was exempted as an essential use. In the United States 25 million pounds of CFCs are used annually in these aerosols.

Patrick G. Spencer
La Crescent, Minn.

Unnamed winner

Thank you for recognizing Copeland Corp.'s Compliant Scroll Compressor technology as important enough to earn a "Best of What's New" award in December 1988's POPULAR SCIENCE. But why didn't you mention our name in the article? It's great when technical and scientific advances are singled out and given recognition in your magazine, but it would be even better if your readers knew who's behind them.

Howard L. Lance
Copeland Corp., Sidney, Ohio

Continued

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An editorial change made after the copy was written resulted in the inadvertent deletion of the reference to Copeland Corp. as the company responsible for the scroll compressor pictured with the item. Though other companies make scroll compressors [Nov. '88], we chose Copeland's for our "The Best of What's New" award because it is—at the moment—the only American-made scroll compressor for home heat pumps and air conditioners. We regret that the item, as printed, omitted that information.

Beating eggbeaters

The item Biggest Eggbeater in November 1988's "Science Newsfront" describes a 500-kilowatt-plus windmill in Texas. May I point out that there is a much larger one at Cap Chat in Quebec, where Hydro-Quebec operates a four-megawatt "eggbeater" that is nearly 350 feet tall?

E. C. Hague
Montreal West, Quebec, Canada

Get a handle on it

The picture of the Pontiac Banshee ["Automotive Newsfront," Dec. '88] shows a car with no door handles. It reminds me of the 1946 Lincoln I had: When the doors froze shut, I stayed home.

E. B. Kilpatrick, Niota, Tenn.

Ring of truth

Upon seeing the ring on the finger of the radiator mechanic ["Doctor Radiator," Jan.] I was unpleasantly reminded of the task of cutting the ring off the finger of a friend after it became the link between a hot battery terminal and ground. When working around any machinery or electrical risk, rings should be removed.

P. O. Kolbe, Newtown, Conn.

Radialgear revisited

In July 1985 POPULAR SCIENCE ran an article about a new transmission for bicycles ["One-Thumb, 15-Speed Shift"]. Called Radialgear, it was invented by Royce Husted. The article mentioned that the transmission might be featured on a bicycle offered through Montgomery Ward, but I haven't seen it in any of their stores. Could we have an update?

L. Daniel Halliday, Stockton, Calif.

The developers of the Radialgear bike transmission (Saroy Engineering, Lisle, Ill.) spent the past three years negotiating with major bike manufacturers

but were unable to reach an agreement to produce bikes equipped with the ingenious gear changer. Now, says inventor Royce Husted, a new line of bikes bearing the trademark Radialgear has been developed by Saroy and will be test marketed in the spring. POPULAR SCIENCE will report on the variable-sprocket shifter's progress in a future issue.—Stuart F. Brown

Shifting speeds

In the December 1988 "Automotive Newsfront" item Softer, Tougher, Toyota recommends a 50-mph maximum speed for shifting from two-wheel drive to four-wheel drive. But an advertisement on the next page states that the 1989 pickup can be shifted to four-wheel drive at any speed. Who's right?

Ralph Nobel, Dallas, Pa.

It is correct that Toyota recommends shifting from 2 High to 4 High at speeds of no more than 50 mph. In most real-world situations the determinations to shift into four-wheel drive is of course made at much slower speeds, when the loss of two-wheel-drive traction has slowed the vehicle. Incidentally, Toyota's 4WDemand does offer one advantage over other shift-on-the-fly systems. It can be shifted from 4 High to 4 Low while moving. Toyota recommends this be done under 5 mph for manual transmissions and up to 18 mph for automatic trucks.—Mike Michels, Toyota Motor Co., Torrance, Calif.

Safer quicksand?

I never know who to ask questions like this. When my mother was in Anchorage, Alaska, a woman drowned while stuck in quicksand in the Turnagain Arm. Even though rescuers got there in plenty of time, they couldn't get her loose. Would super slurper ["Science Newsfront," March '88] change the quicksand's consistency enough to have made it possible to get unstuck?

Peggie A. Leifeste, Matawan, N.J.

Developed by the U.S. Department of Agriculture, super slurper is a synthetic polymer capable of absorbing tremendous amounts of water to form a gel. I put reader Leifeste's intriguing question to William Doane, director of USDA's Plant Polymer Research Laboratory. He says it's conceivable that adding super slurper to quicksand might make the stuff more slippery, and therefore make it easier to pull someone out—but he's not sure. He offers to conduct the experiment if there are any volunteers.—Arthur Fisher

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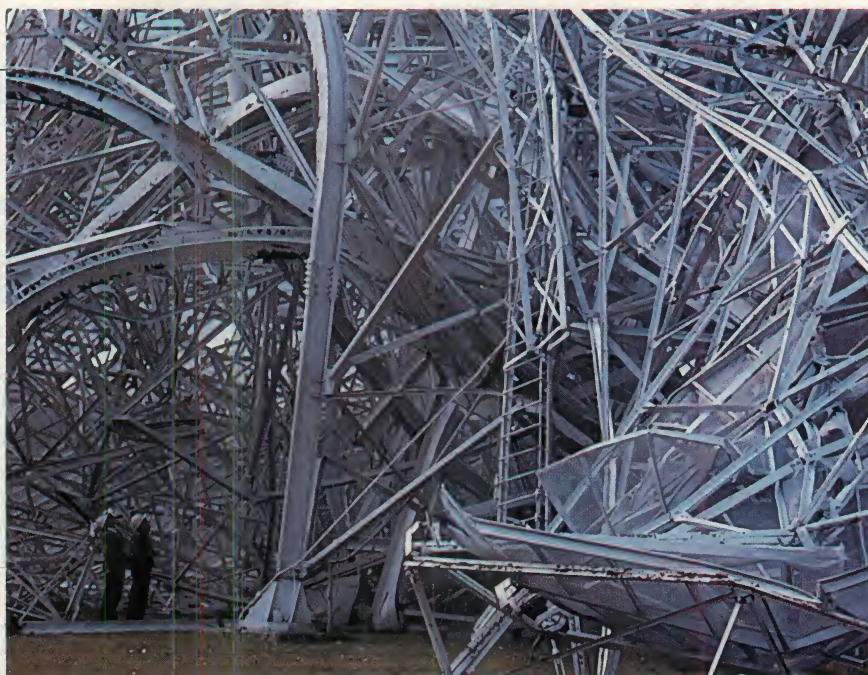
By ARTHUR FISHER

Collapse of a legend

A giant radio telescope is not only an instrument for probing the universe; it can also be an object of intrinsic beauty, a delicate tracery of metal strands forming an intricate mathematical surface.

Such was the 300-foot-wide dish of the National Radio Astronomy Observatory at Green Bank, W.Va., one of the largest such telescopes in the world, a gleaming white paraboloid of aluminum mesh resting on a steel support structure. Sheltered in a mountain hollow from man-made radio interference, for 26 years it had played a major role in a variety of astronomical pursuits, from the search for extraterrestrial intelligence to the discovery of a pulsar at the core of the Crab nebula.

On the night of Nov. 15, 1988, it was participating in the rather humdrum task of compiling a radio sky catalog. At 10 p.m., out of a clear and windless sky, disaster struck. The radio telescope's supporting columns gave way and the great dish collapsed into a tangle of crumpled and twisted metal, leaving what looked like a monument created by a modernist sculptor gone berserk. Part of the failing structure



One of the world's largest radio telescopes, the 300-foot-wide instrument at Green Bank, W.Va., lies in ruins after an inexplicable collapse.

sheared open the roof of the control room below, but missed the dumbfounded telescope operator and his computers.

"It was a really elegant telescope... it's sad to look at it now—just an utter ruin," said the facility's director, Paul A. Vanden Bout, when I spoke to him a month after the collapse. He reported that the causes of the failure "are even more mysterious now than at first, despite the fact that we have two expert teams of investigators probing the failure—including the engineer who had closed New York's Williamsburg Bridge."

Even though there are larger radio telescopes elsewhere—the dish at Arecibo in Puerto Rico has a diameter more than three times as great—the Green Bank instrument was unique in combining high enough sensitivity to detect faint objects with the ability to cover the entire northern sky. It will thus be sorely missed. "Radio astronomy is going to be pretty tough without it," said one expert.

The telescope cost \$850,000 to build in 1962; replacing it would cost at least five times as much and take at least two years.

Magic angle spin

The artist's concept at left shows the key element in a clever new technique developed by scientists at the Lawrence

Berkeley Laboratory and the University of California, Berkeley, for greatly increasing the resolution obtained in NMR (nuclear magnetic resonance) spectroscopy ["Sharpest Look Yet Inside the Body," June '88]. The method is called "double rotation" NMR and involves spinning a solid sample around two axes simultaneously, like a top within a top. It can improve by a factor of 100 the accuracy with which researchers can pinpoint atoms within a solid.

NMR spectroscopy of solids tends to be more subject to "smearing," or blurring, of the frequencies obtained than the same technique used with liquids, because magnetic and electrical interactions among the atoms in a rigid lattice are more difficult to average out. One early approach to this problem was "magic angle spinning," developed in the 1950s. A sample is rapidly spun around an axis that makes an angle of 54.74 degrees with an applied external magnetic field. The rotation simulates the natural tumbling motions that would be encountered in liquids and averages out some of the smearing effects. However, the technique is effective—100 times improvement in resolution—only for atoms with spherical nuclei, such as carbon 13. For the much larger group of atoms with nonspherical nuclei, including oxygen 17, resolution improves only three or four times.

Continued



A new technique for NMR spectroscopy spins a solid sample around two different axes in a magnetic field to achieve better frequency resolution.

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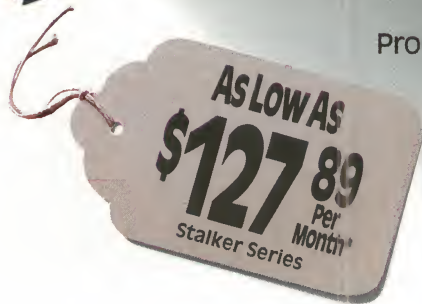
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	Stalker 160	16'4"	80"	100 HP	1050 lbs.
	Stalker 170	16'10"	82"	90 HP	1100 lbs.
	Stalker 170	16'10"	82"	115 HP	1100 lbs.
	Stalker 180	18'	86"	115 HP	1200 lbs.
	Stalker 180	18'	86"	150 Mag II	1200 lbs.
	Stalker 190	19'10"	88"	150 Mag II	1550 lbs.
	Stalker 190	19'10"	88"	200 HP	1550 lbs.
Dual Console Models	Tourney 180	18'	86"	150 Mag II	1200 lbs.
	Tourney 190	19'10"	88"	150 Mag II	1550 lbs.
	Procaster 180	18'	86"	150 Mag II	1300 lbs.
	Procaster 190	19'10"	88"	150 Mag II	1650 lbs.
	Procaster 190	19'10"	88"	200 HP	1650 lbs.

*Based on Manufacturer's Suggested Retail Price of \$8,790.00, with approved credit at participating MMAC financing dealers. Payment based upon down payment of 20% (cash or trade) plus taxes, license and fees; 12.99% APR. Procraft dealer can provide additional details. Term is 84 months. We reserve the right to change prices and specifications without notice. Photos may include optional equipment.

If You Can't Decide Between A Fishing Boat Or A Ski Boat, Get Them Both.



Family Fisher™ 190

Trailer: Procraft color coordinated, drive-on style trailer with 14" mag wheels with bearing protection, tongue jack, roller side guides and submersible lights



Family Fisher™ 160

Procraft Fish & Ski Series

If you're looking for a fishing boat and a ski boat, choose from one of our versatile fiberglass fish & ski packages that let you fish in the morning and ski that afternoon. Each one is fully equipped and ready to go, and includes these *exclusive* features:

- Quicksilver™ stainless steel propeller
- Procraft Stem-to-Stern limited warranty

Shop and compare. You'll soon see, feature for feature, nobody gives you what we can give you. For complete product information and the name of your nearest Procraft dealer, call:

1-800-526-6630

Model	Length	Beam	Mariner Engine	Boat Weight
Family Fisher 160	16'4"	80"	75 HP	1050 lbs.
Family Fisher 170	16'10"	82"	115 HP	1100 lbs.
Family Fisher 180	18'	86"	115 HP	1220 lbs.
Family Fisher 180	18'	86"	150 HP	1220 lbs.
Family Fisher 190	19'10"	88"	150 HP	1550 lbs.

*Based on Manufacturer's Suggested Retail Price of \$10,490.00, with approved credit at participating MMAC financing dealers. Payment based upon down payment of 20% (cash or trade) plus taxes, license and fees, 12.99% APR. Procraft dealer can provide additional details. Term is 84 months. We reserve the right to change prices and specifications without notice. Photos may include optional equipment.

Try One Of Our Fishing Boats And You'll Be Hooked For Life.



As Low As
\$95⁴⁴
Per Month*
Crappie Series

Trailer: Procraft custom-built color coordinated, drive-on style trailer with 14" mag wheels with bearing protection, tongue jack, roller side guides and submersible lights



	Model	Length	Beam	Mariner Engine	Boat Weight
Aluminum	Crappie Hunter 1560	15'	60"	25 HP	395 lbs.
	Crappie Hunter 1673	16'	73"	25 HP	540 lbs.
	Crappie Hunter 1673	16'	73"	40 HP	540 lbs.
Fiberglass	Crappiethon 150	15'5"	76"	40 HP	825 lbs.
	Crappiethon 160	16'4"	80"	60 HP	1050 lbs.

*Based on Manufacturer's Suggested Retail Price of \$6,560.00, with approved credit at participating MMAC financing dealers. Payment based upon down payment of 20% (cash or trade) plus taxes, license and fees, 12.99% APR. Procraft dealer can provide additional details. Term is 84 months. We reserve the right to change prices and specifications without notice. Photos may include optional equipment.

Procraft Crappie Fishing Series

It's everything you want in a fishing boat. Performance. Reliability. And loaded with all the features serious fishermen demand in their rigs, including these *exclusive* Procraft features:

- Quicksilver™ stainless steel propeller
- Procraft Stem-to-Stern limited warranty

In fact, they've got it all. Just shop around and compare for yourself. You'll soon see that, feature for feature, nobody gives you more for your money than we do.

For complete product information and the name of your nearest Procraft dealer, call:

1-800-526-6630

This Could Be The Beginning Of A Great Fish Story.



Procraft Aluminum Fishing Series

If you really want to catch those lunkers, our Bass Hunter™ is for you. It's quick. Tough. And loaded with everything you could ever want in a fishing boat, including this *exclusive* feature:

- Procraft Stem-to-Stern limited warranty

Or if you need a smaller, versatile boat, select one of our Outdoorsman models. Nobody gives you more features for your money than we do. Just shop around and compare for yourself.

For complete product information and the name of your nearest Procraft dealer, call:

1-800-526-6630

Model	Length	Beam	Mariner Engine	Boat Weight
Bass Hunter 1673	16'	73"	25 HP	555 lbs.
Bass Hunter 1673	16'	73"	40 HP	555 lbs.
Bass Hunter 1773	17'	73"	40 HP	700 lbs.
Bass Hunter 1773	17'	73"	60 HP	700 lbs.
Bass Hunter 1773 Pro-Deck	17'	73"	40 HP	745 lbs.
Bass Hunter 1773 Pro-Deck	17'	73"	60 HP	745 lbs.
Bass Hunter 1773 Pro-Deck	17'	73"	75 HP	745 lbs.
Outdoorsman 1456	14'	56"	4 HP	200 lbs.
Outdoorsman 1456	14'	56"	15 HP	200 lbs.
Outdoorsman 1667	16'	67"	8 HP	295 lbs.
Outdoorsman 1667	16'	67"	20 HP	295 lbs.
Outdoorsman 1573	15'6"	73"	20 HP	300 lbs.
Outdoorsman 1573	15'6"	73"	25 HP	300 lbs.

*Based on Manufacturer's Suggested Retail Price of \$6,990.00, with approved credit at participating MMAAC financing dealers. Payment based upon down payment of 20% (cash or trade) plus taxes, license and fees, 12.99% APR. Procraft dealer can provide additional details. Term is 84 months. We reserve the right to change prices and specifications without notice. Photos may include optional equipment.

Now You Can Afford To Take That Long Summer Cruise.



Model	Length	Beam	Mariner Engine	Boat Weight**
Fishchaser 20	20'	8'	25 HP	1100 lbs.
Fishchaser 20	20'	8'	40 HP	1100 lbs.
Funchaser 20 LE	20'	8'	25 HP	1100 lbs.
Funchaser 20 LE	20'	8'	40 HP	1100 lbs.
Funchaser 24	24'	8'	25 HP	1700 lbs.
Funchaser 24	24'	8'	50 HP	1700 lbs.
Funchaser 24 LE	24'	8'	40 HP	1700 lbs.
Funchaser 24 LE	24'	8'	75 HP	1700 lbs.
Funchaser 28 LE	28'	8'	40 HP	2310 lbs.
Funchaser 28 LE	28'	8'	75 HP	2310 lbs.
Voyager 28	28'	8'	90 HP	3200 lbs.

*Based on Manufacturer's Suggested Retail Price of \$6,980.00, with approved credit at participating MMAC financing dealers. Payment based upon down payment of 20% (cash or trade) plus taxes, license and fees, 12.99% APR. Procraft dealer can provide additional details. Term is 84 months. We reserve the right to change prices and specifications without notice. Photos may include optional equipment.

**Boat weight only

Procraft Pontoon Series

If you just want to do a little floating, bask in the sun, barbecue with the family and maybe do a little fishing, this is the perfect rig for you. Each pontoon boat is fully equipped with everything you need for fun on the water, including these *exclusive* features:

- Pressure-treated tongue & groove marine grade wood floor with plush marine grade carpeting
- Procraft Stem-to-Stern limited warranty

Feature for feature, nobody gives you more for your money than Procraft. Compare our features to other packages and see for yourself.

For complete product information and the name of your nearest Procraft dealer, call:

1-800-526-6630

In the new technique, pioneered by a team led by Alexander Pines, a chemistry professor at Berkeley, the limited resolution for nonspherical nuclei is overcome by providing a second magic angle of 30.56 degrees, as shown in the illustration. The half-inch-diameter cylindrical holders are suspended on air bearings and spun by jets of air to rotation speeds of about half a million revolutions per minute. The addition of this second spin angle provides a complex motion that succeeds in averaging out almost all the smearing effects that previously plagued such analysis.

The greatly improved results with oxygen 17 are deemed particularly significant because of recent discoveries that many oxides are high-temperature superconductors ["Superconductivity," April '88]. The new technique may help physicists explain the still-mysterious behavior of these materials.

Fleet foot

One approach to making a lifelike and responsive prosthetic foot for amputees appears in this photo. It is the Carbon Copy II, made by the Ohio Willow Wood Co. in Mt. Sterling, Ohio, and, says designer Robert Arbogast, "It gives the amputee enough bounce to run and jump." The springiness comes from energy-storing carbon deflection plates and a lightweight keel (they are seen at the bottom of the photo), which uses Du Pont Kevlar aramid fiber. The plates flex under the weight of a step, store a part of the force exerted, then discharge energy as they return to their primary position. The lightweight keel, explains Arbogast, allows a smooth, pendulum follow-through motion.

The lifelike appearance of the device is attributable to a newly developed flexible microcellular urethane foam.

Beating time, time, time

Shortwave station WWV, operated by the National Institute of Standards and Technology (formerly the National Bureau of Standards), has for years been broadcasting highly accurate time signals from its Ft. Collins, Colo., home. Now it is going to help unscramble the car-clogged routes of Los Angeles County. The station's signal will synchronize traffic lights in selected corridors by means of electronic con-

trollers installed at each location and tuned to WWV. Individual stoplights will be prevented from drifting out of sync by even a few seconds, and motorists should benefit.

Superconducting wire

For the first time, according to a spokesman for the University of Michigan's College of Engineering, a flexible wire only $\frac{1}{8}$ inch wide has been formed from one of the new high-temperature ceramic superconductors. Invented by a professor of mechanical engineering, Shyam K. Samanta, the wire material is a composite of metal, metal oxide, and the previously known supercon-



The Carbon Copy II prosthetic foot uses a combination of synthetic compounds to put a spring in a user's step.

ductor called 1-2-3 yttrium-barium-copper oxide. Samanta also devised a new process for extruding the material through a die at the relatively low temperature of 450 degrees C. The wires produced are bendable, contain no microscopic cracks, and do not disintegrate when they are exposed to the environment.

Earthquakes and supercities

"By an accident of geography, many of the world's highest population densities in developing countries are found near sites of historical earthquakes. There, urban planners are more concerned with providing shelter than ensuring the longevity of cities."

So said University of Colorado at Boulder Professor Roger Bilham at a meeting of the American Geophysical Union last December in San Francisco. He warned that the deadly coincidence of major quake sites and "supercities" could mean unprecedented disasters—especially in a quake of magnitude 7.0

or more on the Richter scale. (The recent catastrophic Armenian quake registered 6.9.) Of the estimated three billion people who will be living in cities at the end of this century, Bilham said, some 290 million will live in supercities—with populations of two million or more. Of these roughly 100 supercities, 41 are located within 120 miles of either a major tectonic plate boundary or the site of a damaging earthquake in the past. Such cities include Mexico City; Jakarta, Indonesia; and Tehran, Iran.

Bilham suggests that new, more-precise techniques of space geodesy—measuring the shape of earth's surface via satellite—could help forecast impending quakes in such areas. The earth's crust often deforms before a quake; current methods can monitor the surface horizontally and vertically with an accuracy of one inch.

"Global change is driven... by a rapidly increasing population," Bilham said. "If we can accurately monitor these crustal changes... quake forecasts could significantly lessen major social disruptions."

Help! Fire (ants)!

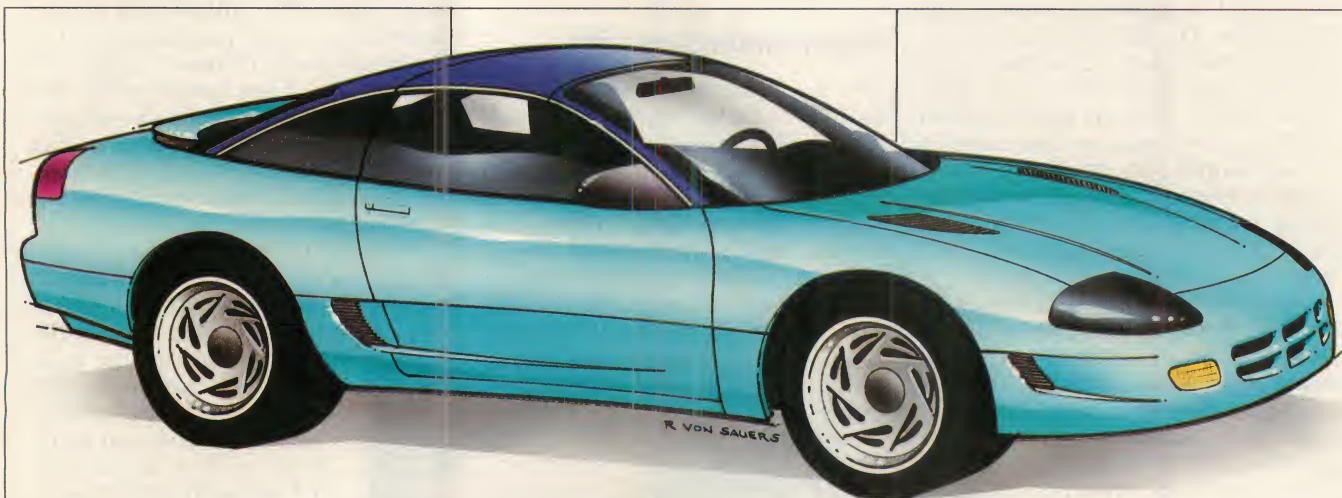
When the government chose a Texas location for the site of the proposed \$4.4-billion Superconducting Super Collider ["The World's Biggest Machine," June '87], howls went up from competing states, claiming, among other things, unfair political considerations.

Now, to add to the uproar, comes the Department of Energy's own 10,000-page environmental impact statement. What's the problem? Fire ants. The site is absolutely crawling with these insect pests. With their painful stings and voracious appetites, they are the bane of many parts of the South, and some 30 years of control programs have been only partially effective. The problem for the Super Collider is that the ants chew right through underground electrical cables, causing power outages. "Fire ants," the report said, "appear to be attracted to electrical equipment and can cause shorts by chewing through insulation and by crowding into spaces around electrical contacts."

The DOE report says special measures will be needed to protect wiring—and construction workers—from the onslaught of the ants. P.S.

Automotive Newsfront

By **DAN McCOSH** Detroit Editor with Timothy O. Bakke, Brian Nadel, and Herbert Shuldiner



Chrysler's planned supercar bears a resemblance to the Diamond Star pair: Chrysler Laser and Mitsubishi Eclipse.

Future Chrysler cars

Chrysler's next joint venture with its Japanese affiliate Mitsubishi is expected to produce a 160-mph supercar with a full complement of Mitsubishi-derived technology, including four-wheel steering and four-wheel drive. With an estimated 0-to-60-mph time of six seconds, the new four-seat coupe could reestablish Dodge in the high-performance arena, where it has been absent since the 1960s.

The project is expected to yield two lines built on a common chassis, but with separate body panels. Other features of the new Dodge line (which might carry the name Conquest) include anti-lock brakes, adjustable suspension, and a standard five-speed.

Two models of the Dodge are anticipated: a base model in the \$18,000 range, powered by a three-liter V6 with multiport fuel injection, and a supercar with 260 hp via twin turbos breathing through a pair of intercoolers. Chrysler also still plans to restyle its current Daytona model in 1991, say company officials, and will soon introduce the Eagle Talon—another Mitsubishi-based product.

Meanwhile, a two-seat roadster unveiled by Chrysler at the Detroit auto

show is the latest incarnation of Carroll Shelby's dream to beat the performance of his original 427 Cobra. The show car is powered by a high-output version of a proposed V10 truck engine.

Fast cat

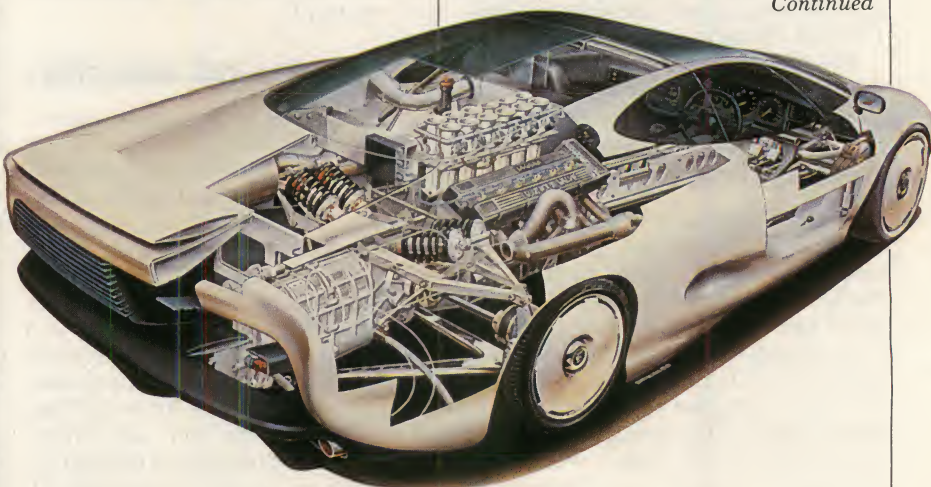
Jaguar recently rolled out its XJ220 supercar that is aimed squarely at the Porsche 959 and Ferrari F40. The car, whose top speed is said to be in excess of 200 mph, is powered by a mid-mounted 6.2-liter V12 engine rated at 500 hp. With power to spare, the supercat can accelerate to 60 mph in a scant 3.5 seconds and top 100 mph in as little as 4.5 seconds later. Wrapped in an epoxy-bonded aluminum monocoque with an outer aluminum skin, this feline has a coefficient of drag between 0.35 and 0.38, depending on ride height

and the position of its adjustable air foil.

The aluminum V12 engine is an enlarged version of Jaguar's 5.3-liter XJS power plant, though with major tweaks. The twin-cam 48-valve heads came from a mid-'60s racing project. All four wheels are driven via three viscous limited-slip differentials, with 31 percent of the torque going to drive the front wheels and 69 percent to the rear. The racing style rear suspension has a pair of coil/shock units on each wheel that is attached directly to the five-speed transmission.

Unlike the stark Ferrari F40, the Jaguar juggernaut is fully equipped with lavish amenities. The climate-controlled cockpit is leather lined and comes with a compact-disc player. Interested? Expect to pay about \$350,000, and wait until 1991 (or later).

Continued



Beneath the XJ220's sleek aluminum-on-epoxy skin sits Jaguar's 500-hp V12. This prototype has race-style twin coil spring/shock units attached directly to the five-speed transaxle, located behind the mid-mounted V12 engine.

TOYOTA TRUCKS

Meet Your Next Truck.

If you believe you can't improve on perfection, shake hands with the all-new Toyota 4x4 Xtracab SR5 V6. From the bold, new grille to the rugged, double-wall bed, aggressive design marks the '89 Toyota as the industry leader once again. But it doesn't only look aggressive; the improved 150-hp. V6 powerplant ensures that it is. And, the new 4WDemand lets you get all that power to all four wheels without even slowing down. In addition, the completely redesigned interior boasts a new cockpit-style wrap-around dash and the spacious Xtracab makes room for two extra adults, thanks to the new forward-facing jump seats.

So if you know about 4x4's, there's no need to introduce Toyota. But test drive the new SR5 V6 and you will meet your next truck.

Toyota's 36-mo./36,000-mi. Limited Warranty

You're covered with Toyota's 36-mo./36,000-mile basic new vehicle limited warranty.* No deductible, no transfer fee, and a 5-yr./unlimited-mileage warranty on corrosion perforation. See your Toyota dealer for details.

TOYOTA QUALITY

WHO COULD ASK FOR ANYTHING MORE!



Get More From Life... Buckle Up!

Light bar does not provide crash protection.

*Except normal wear and maintenance items.

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information and nearest dealer location.

Porsche challenger

The Volkswagen Scirocco is, well, gone with the wind as far as the United States is concerned. Soon a new supercharged coupe called the Corrado will take its place. Volkswagen hopes the \$20,000 Corrado will become an "inexpensive" alternative to the Porsche 944. **POPULAR SCIENCE** Editor Herbert Shuldiner recently tested a Corrado on a drive from Paris to VW headquarters in Wolfsburg, West Germany. He reports that the Corrado is loaded with exciting new engineering features, including a rear air spoiler that deploys at 45 mph to reduce aerodynamic rear-end lift by 64 percent. The wing automatically retracts at 25 mph to improve rear visibility.

But the most important technology in the Corrado isn't new. In fact, the idea for its G-Lader supercharger is over 80 years old. However, nobody could mass-produce the spiral-design supercharger until recently. The G-Lader helps the 1.8-liter four-cylinder engine produce 158 hp. And the power is instantly available when you step on the accelerator. Because the supercharger is belt-driven off the engine, the turbine instantly forces more fuel-air mix into the cylinders to provide more power. Turbochargers, by comparison, are driven by hot exhaust gases and normally have a momentary lag before the engine receives the boost. The Corrado cruises comfortably at 100-mph-plus speeds on the autobahns and has a stable ride on all road surfaces—wet and dry. Handling of the front-engine rear-drive sports car is excellent. How does it compare with the Porsche 944? The **POPULAR SCIENCE** test team will run the cars head to head in an upcoming car test.

Once and future Porsche

In the hands of any other auto company, a three-liter four-cylinder engine would be best suited to pulling a plow. But for the 1989 Porsche 944, modern engine-balancing technology is used in one of the largest production four-cylinder engines in recent times, and the result is an engine smooth enough for—a Porsche.

Large displacement four-cylinder engines normally suffer from shaking forces inherent in the basic design, but twin counterrotating balance shafts in Porsche's all-aluminum 944-series engines dampen virtually all perceptible rotating vibration. Porsche has enlarged the base engine from 2.5 liters to 2.7, and offers the three-liter 208-hp engine as an option. A turbocharged

Continued



The Mazda MX-5 Miata two-seater roadster is built on a 89.2-inch wheelbase with double wishbone suspension, front

and back. Rear wheels are driven by a 16-valve 116-hp version of the 1.6-liter engine from the 323 line.



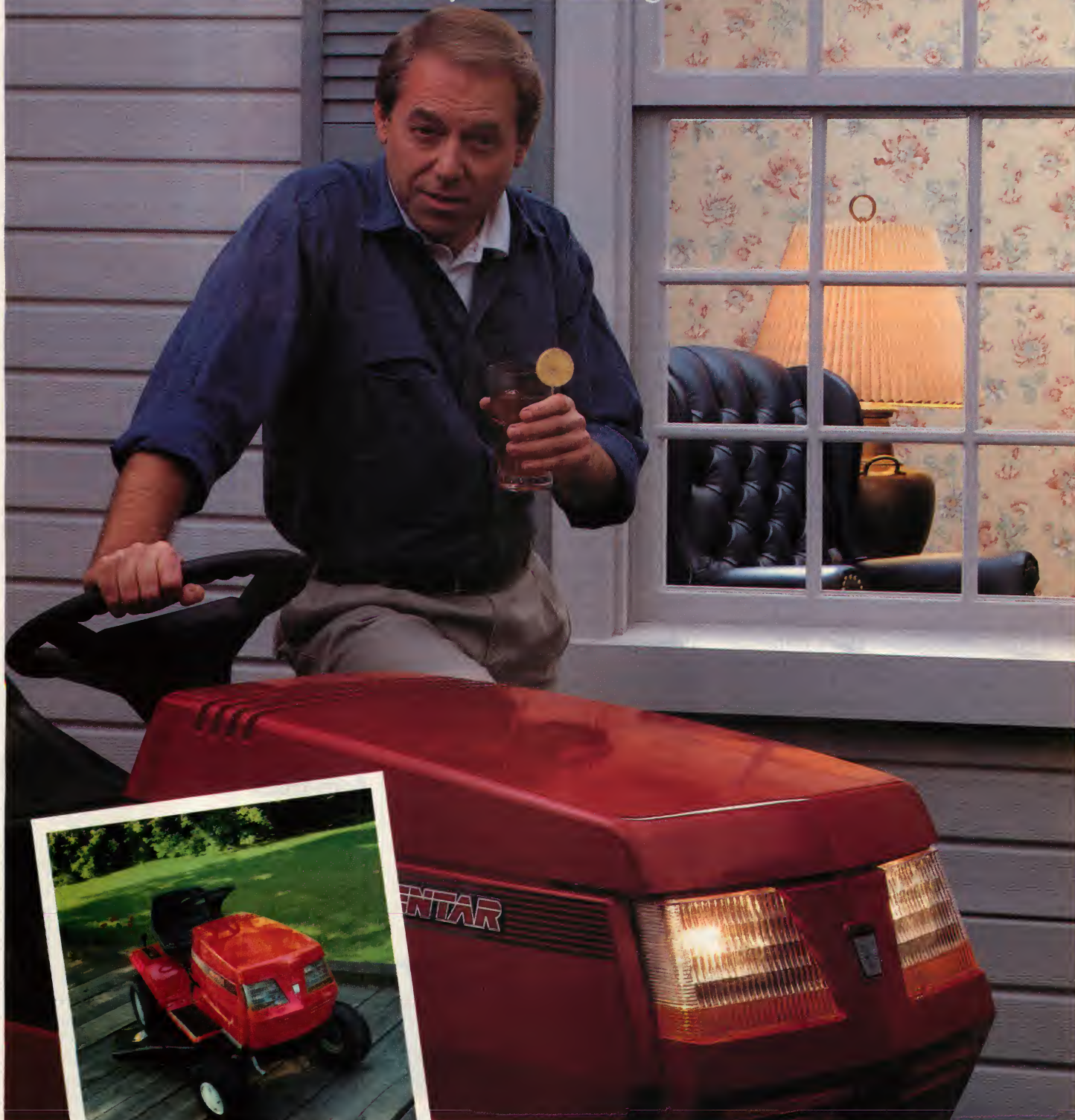
VW's G-Lader spiral supercharger boosts the Corrado's 1.8-liter engine to 158 hp, good for a 0-to-60 time of 7.3 seconds. With a \$20,000 price sticker the Corrado is expected to give the Porsche 944 a run for the money.



The Mercedes-Benz SL coupe takes a few quick laps at the Stuttgart test track prior to its summer introduction.

Engine options: 12- or 24-valve three-liter straight six (300SL and 300SL-24) or the five-liter V8 (500SL).

Look, it would have been easy to spend
more money, but I bought value.



This Sentar has everything I wanted in a lawn tractor. It's built smart, built to last. It has a style all its own, and it comes loaded with features.

Like the 12.5 horsepower overhead valve twin cylinder engine. Smoothest thing on the market. And a no-clutch transmission with 7 forward speeds. And the most sophisticated 38" deck and grass collection system I could find.

Sure, I looked at the big names. But I bought a Sentar because the value is in the machine, not in the name.

Besides, I never could resist a red tractor.

For a free color brochure on all SENTAR models, contact:

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SENTAR
IF YOU BELIEVE IN VALUE.



PHOTO BY TIM ANDREW

The profile of the \$69,500 Porsche 911 Carrera 4 is little different from that of other 911s. One distinguishing detail, however: At 50 mph the electrically powered rear spoiler magically rises from its flush position on the rear hood, only to fully retract at about 6 mph.

version of the 2.7-liter engine produces 247 hp.

While all the changes spell out increased performance, the extra torque of the three-liter engine gives it more flexibility around town, while the turbocharged engine comes into its own in high-speed driving. Aside from the increased displacement, the new engine lineup has a modified cooling jacket that is restricted to the upper half of each cylinder—a feature that Porsche says it developed in its racing engines.

The low-speed response of the new three-liter engine makes for pleasant driving. Splitting the 208 hp four ways still makes for some noticeable grumbling. The engine suffers mainly by comparison with the free-revving turbo, rather than against competitive engines from other manufacturers. Porsche's front-engine rear-transmission remains the best-balanced arrangement available in a sports car today. Unfortunately, the refinements push the 944's price over \$40,000, a rarefied altitude for a two-seat sports car.

Porsche 911—with 4WD?

Senior Editor Tim Bakke drove the new

Porsche 911 Carrera 4 in Nice, France. Here is his report.

You see the new Carrera 4 parked on a street. But unless you happen to see the little "4" after "Carrera," you might not recognize it as the milestone it is. It looks for all intents and purposes like just another 911, the car that for 25 years has fascinated the initiated and awed just about everybody else. Don't be fooled. Only 15 percent of the all-wheel-drive Carrera 4's parts are carried over from the old 911. Other than most of the body shell, the seats, the instrument-panel layout, and about a fifth of the engine parts, the new car is just that—new. From the four-wheel-drive mechanicals, derived from the already-legendary 959, to the twin-ignition 250-hp 3.6-liter flat-six engine, to the heating and air-conditioning system, the Carrera 4 is a changed beast. In fact, just about everything under the skin is all new.

With a claimed 0-to-60-mph acceleration of just under six seconds and a top speed of 160 mph, the Carrera 4 is, naturally, a true driver's car. The four-wheel-drive system uses two micro-processor-controlled hydraulic multi-plate clutches, one between the front and rear axles and another between

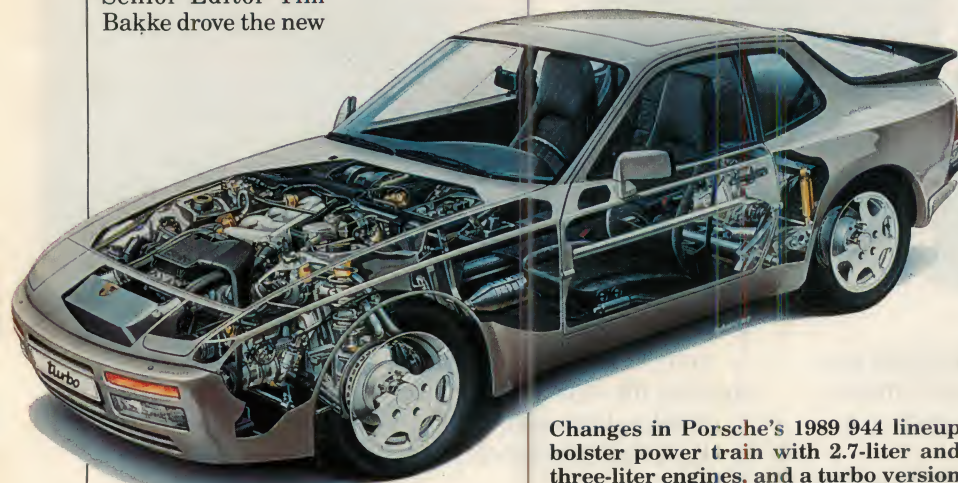
the left and right rear wheels to manage torque split and maintain traction under tricky conditions. While tooling around twisty country roads near the French Riviera, the car demonstrated sedate manners, with barely a hint of lift-throttle oversteer in even the most pulse-quickenings maneuvers. Porsche engineering leader Dr. Helmuth Bott says lateral and longitudinal acceleration sensors, with ABS wheel-speed sensors, feed data to the computer, which maintains traction at all four corners. Some of the credit for the exquisite handling must go to the new independent coil-spring suspension and toe-correcting bushings used in the rear axle. With a front-rear torque split of 31:69, the car maintains the traditional Porsche feeling of rear-weight bias, and about the only thing you'll notice in the all-wheel-drive system is what the car doesn't do when you push it a little too hard.

Aero-truck

Cars have long been the center of attention for wind-cheating aerodynamic styling, but what about freight-hauling trucks. Besco Bodies of Northampton, England, has designed and built a Leyland DAF truck box with an exceptional 0.325 coefficient of drag—enviable by car standards, and phenomenal for trucks. Work on half-scale models at the Motor Industry Research Association wind tunnel led to the use of rounded roof and cab air dams and a downward sloping roof line. Based on controlled track testing, fuel economy improved by 20 percent at 40 mph and an astounding 40 percent at 60 mph. All told, the modifications cost less than \$2,000.

Window hanger

A new window hinge developed by Sheller-Globe uses a one-piece plastic window seal and a flexible membrane hinge. It's particularly suited to opening rear-quarter windows. **[E]**



Changes in Porsche's 1989 944 lineup bolster power train with 2.7-liter and three-liter engines, and a turbo version of the 2.7-liter four. Twin balance shafts help to reduce high rev vibrations.

Over-achiever.

This is an extremely ambitious cigarette. Even though it is an ultra light, it promises to deliver a richer, more satisfying taste than you'd ever expect at such low tar levels. And judging by the fact that it has quickly become one of America's fastest growing brands, Merit Ultra Lights is fulfilling that promise. Enriched Flavor™ is the reason why. Only Merit has it. So raise your expectations of ultra low tar. Switch to Merit Ultra Lights.

Enriched Flavor,™ ultra low tar.

A solution with Merit.



Merit Ultra Lights

**SURGEON GENERAL'S WARNING: Quitting Smoking
Now Greatly Reduces Serious Risks to Your Health.**

© Philip Morris Inc. 1989

Kings: 5 mg "tar," 0.5 mg nicotine av. per cigarette by FTC method.

Electronics Newsfront

By WILLIAM J. HAWKINS



Big-screen video: The largest electroluminescent screen is Planar's 18-inch 1,024-by-800-pixel flat panel.

Bigger screens keep coming

Turn on a computer that uses an electroluminescent (EL) display, and you'll see a bright, extremely clear image from the tough solid-state panel. But until now you couldn't see a big one.

Planar Systems in Beaverton, Ore., has created an 18-inch EL display. "AC Thin Film EL technology has leapfrogged from nine-inch diagonal, the largest display previously available, to Planar's eighteen-inch diagonal, high-resolution display,"

says Planar's president, James Hurd.

The 11.5-by-13.6-inch monochrome viewing area contains 820,000 addressable pixels arranged in a 1,024-by-800-pixel matrix. According to the company, the large size was possible because of a single-pass manufacturing technique. Like other EL panels, which contain phosphor material sandwiched between row and column electrodes, Planar's panels are assembled in a vacuum. But unlike the others, which are made a layer at a time, there is no vacuum break in the one-pass process. That helps to eliminate contamination and make a large usable size possible.

"A display this size can be used for a wide variety of applications," says Hurd, "from government strategic and tactical transportable systems to commercial terminals and work stations." Prototypes of the 15-pound panel are available for \$20,000.

Meanwhile, liquid-crystal-display technology isn't standing still. MRS Technology in Chelmsford, Mass., has created PanelPrinter—a machine that stamps out high-resolution 18-inch active-matrix color LCDs like a cookie cutter. The result of the high-yield system will ultimately be lower costs for pocket TVs and portable PCs of the future.

Double vision

Talk about a squeeze play: Sony's new rear-projection TVs let you see two shows at once by compressing the two images onto the same 46-inch screen (see photo). There's an instant-replay feature too. Press a button and the last two seconds of images are replayed on the screen. Prices start at \$4,000.

Eight-hour camcorder

RCA's CC310 full-size VHS camcorder can record your home-movie session for up to (ugh) eight hours on one cassette. Fortunately, you can easily shorten it later with the unit's built-in editing features like flying erase head, video-audio dub, microphone mixing, and edit search. It's \$1,399, but for another \$100 there's a second model, CC320, which contains a clever video titler. Instead of fumbling through a miniature keyboard to select letters in a title, you turn a small knob back and forth. The knob lets you scroll through the alphabet on the screen. Release the knob

Continued



How do you get two full-size TV pictures on one screen? Easy, claims Sony,

just squeeze them in. Two channels are shown at once on the 46-inch display.

when the letter you want appears and press a button to freeze it in place. Complete words and sentences are made quickly, easily, and without taking your eye off the subject.

Denser disks

It's a 3.5-inch magnetic floppy diskette with one addition: an optical servo track embedded into its surface. The track is used to align the magnetic read-write head more precisely. That lets up to 10 times more data—up to 25 megabytes—be held on the small disk. Made by Insite Peripherals (Santa Clara, Calif.), the disk and drive works on any computer that has an SCSI interface.



Optics and magnetic media merge with Insite Peripherals' 3.5-inch 25-megabyte Floptical disk.

Bits and ...

- Philips has demonstrated its high-definition TV system via simulated satellite transmission at its Briarcliff Manor, N.Y., laboratory. The picture quality I saw, from still and moving scenes shown on 31- to 120-inch screens, is excellent. Bottom line: The HDTV race is sure to continue for years.

- MCI has begun the first long-distance network that is dedicated to domestic and international facsimile messages.

- Philips and Warner Brothers are devising an LCD-panel system for the back of airline seats. Called Airvision, the personalized screen will show films, sports, news, documentaries, and TV shows.

... bites

- "In the Clear," a new TV program made just for satellite-dish owners by the American Home Satellite Association, had to be postponed due to a transponder failure.

- Computers have tried to replace everything from secretaries to statisticians, but now the most difficult job

of all is being encroached upon: motherhood. For \$19.95 at B. Dalton Booksellers and Waldenbooks, you can buy the floppy-disk-based, computerized version of *Campbell's Microwave Cookbook*. The floppy diskette is palatable to IBM-PC compatibles.

- Sign of the times: U.S. Customs agents, acting on a tip, recently raided the Crow Indian Reservation in Montana. Their catch: pirated satellite TV descramblers.

- Bellcore has designed an experi-

mental microchip that is capable of learning the way a person does, by example—not by programming—and has become the first neural chip to "learn" the mathematical logic function called exclusive or. "If both inputs are zero, or both inputs are one," announces a press release from Bellcore describing the XOR logic, "then the input should be zero." Oops. Actually the *output* should be zero, not the input. Give it a break. It's only human. P 5



Radar detectors: Which are really best?

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Uniden	Maxon	
Radio Shack	Radio Shack	Uniden
BEL	Uniden	Whistler
Whistler	Fox	TIE Cobra GUL
Sparkomatic	Cobra	
Fox	BEL Vector	Radio Shack
GUL	Snooper	Sparkomatic
	Fuzzbuster	Maxon
	Sparkomatic	
	Sunkyoung	

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Fast-track sedans

Once the private reserve of expensive European models, the sport-sedan class has some new challengers. **POPULAR SCIENCE** pits the new Ford Taurus SHO and Nissan Maxima SE against two redesigned stalwarts, the BMW 535i and Audi 200, and discovers a new pecking order.

By **DON SHERMAN**

One day not so long ago sports cars and family sedans were a breed or more apart. The sports cars had all the fun—true designer styling, zippy handling, a spirited exhaust note, and, if they were lucky, a powerful engine under the hood. The sedans invariably rode on skinny tires. They got by with a wimpy engine and mediocre brakes as long as the ride was comfortable and the back seat had enough room for the kids.

Then America discovered that Europe builds cars too. But the rules of the automotive game are different across the Atlantic. Generally speaking, pure sports cars are frivolous machines seldom taken seriously. The sedan, on the other hand, is the chosen mode of transportation. Start with four doors and comfortable seats for four passengers, add the best engine available, and place the package on a highly refined chassis. Before you know it, you've got a Mercedes-Benz or a BMW: a machine that can beat planes and trains from Munich to Milan while comporting two couples and their luggage in supreme comfort and style.

Sport sedans

Such cars are frequently lumped into the luxury class because they are inevitably expensive, but a better name for them is sport sedans; they have the

verve and vivacity of a sports car matched with the practicality of a family sedan.

The good news is that Europe is no longer the exclusive source of sport sedans. Ford Motor Co., feeling its oats, has mated a potent Yamaha engine with an ordinary-looking Taurus. Nissan has broken from the Japanese compact-sedan mold and upgraded the Maxima in hopes of muscling into this segment. Two established sport-sedan brands, Audi and BMW, also have updates for the 1989 model year, so **POPULAR SCIENCE** assembled this quartet to assess the state of the sport-sedan art.

The Audi 200 is the latest version of the Audi 5000 and, as before, it is powered by a turbocharged and intercooled single-overhead-cam 2.2-liter five-cylinder engine that drives the front wheels. For 1989 the news is a fresh interior and upgraded equipment levels. Anti-lock brakes, a driver's-side air bag, and an anti-theft system are now standard.

The BMW 535i is new from its kidney-shaped grille to its multicolored tail lamps, including mechanicals, even though it looks little different from past models. An SOHC 3.4-liter in-line six-cylinder engine powers the rear wheels.

The Nissan Maxima is also a clean-sheet design that saves only the power train from last year's model—an



Performance with four doors (clockwise

SOHC three-liter V6 driving the front wheels.

Even though the Ford Taurus SHO doesn't look that different from the million or so examples of the marque that are now on the highway, the SHO (super-high-output) designation means something special: a dual-overhead-cam 24-valve three-liter V6 engine, revised suspension settings, fatter wheels and tires, four-wheel disc brakes, new, more-comfortable front bucket seats,



from front): Ford Taurus SHO, BMW 535i, Audi 200, and Nissan Maxima SE show off understated good looks.

and a slightly racier-looking exterior.

At first glance the four test cars don't seem that different. All offer five-passenger seating, their exterior dimensions are close, and engine displacements are similar once you apply a correction factor to the turbocharged Audi. All have modern aerodynamic exterior styling and functional interior layouts. One discrepancy is that the Audi 200 has a three-speed automatic transmission while the other three

contenders have five-speed manual gearboxes.

Of course, each model has a distinctive driving personality, the natural result of two underlying influences: how the major components were arranged in the first place and how each manufacturer refined the hardware during the development process. In other words the Nissan Maxima and the BMW 535i may look similar to the casual observer, but no one would con-

fuse the two cars after a brief test drive.

Interestingly enough, the Europeans do not necessarily lead the way in late-breaking technology. The in-line engines of the Audi and BMW are not as tidy to package as the two Japanese-made V6s. Furthermore, BMW sticks with rear-drive while the majority of the world's large-sedan builders have long ago converted to front-drive. These days four-valve combustion chambers

Continued

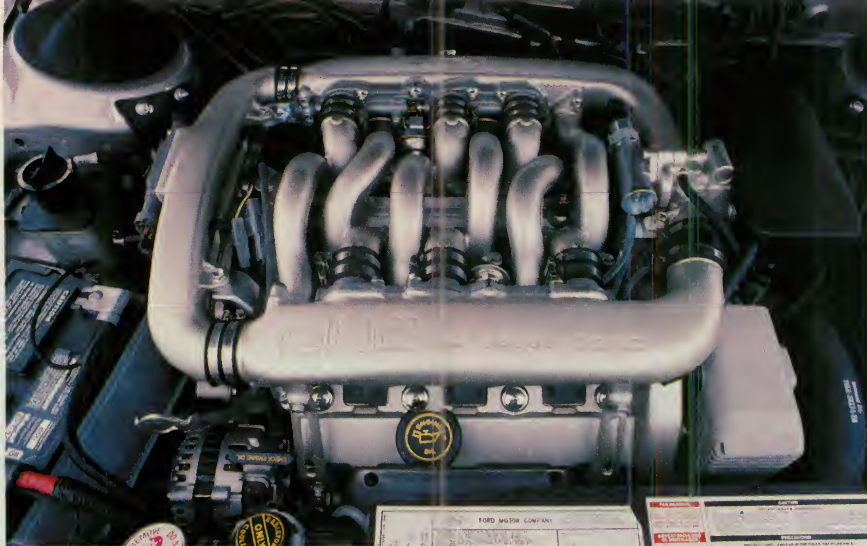


PHOTO BY JOHN B. CARNETT



Fast-track sedans *Continued*

The Taurus SHO's engine (left) is fed by a double-throated intake manifold. Long intake runners breathe at engine speeds up to 4,000 rpm, when a throttle plate opens to kick in six additional shorter runners, pushing the V6 to 220 hp at 6,200 rpm. The needles and numerals of the Maxima's analog gauges show black on white during the day, but switch to white on black at night for better visibility.

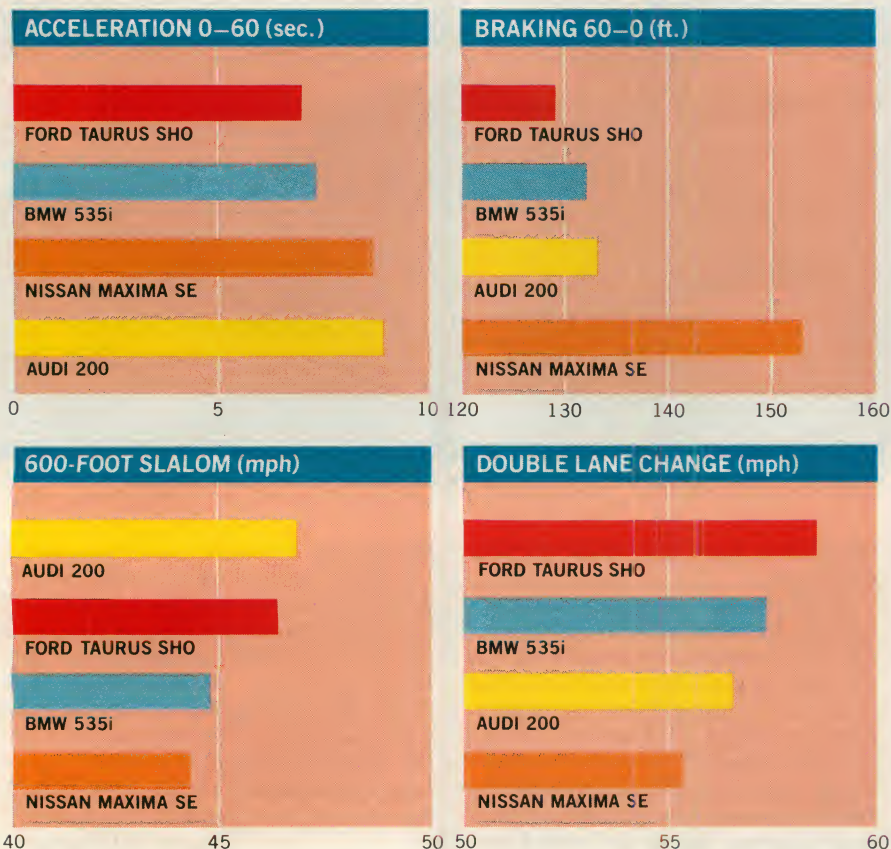
and double-overhead cams are preferred over turbocharging and extra piston displacement for gaining power, one more point against the turbo Audi and larger-displacement BMW.

In terms of specific output, the Ford Taurus SHO rises to the head of the class. With 73.7 horsepower per liter, the 24-valve Taurus beats its closest competition, the turbocharged 10-valve Audi 200, by a small margin (the Audi's specific output: 72.8 hp per liter). The 12-valve BMW and Nissan engines make 60.6 and 54.1 hp per liter, respectively. Clearly, a four-valve combustion chamber is the name of the sport-sedan game. But as we found out at the test track and over the road, how the chef stirs the soup makes more difference than which vegetables went into the pot when what really matters is the taste.

It's soup!

The nervy Taurus, for example, swept the field off its feet at the proving grounds by winning most of the performance tests. The Yamaha-powered Taurus SHO is the quickest accelerating (to 60 mph), shortest stopping (with warm brakes), best handling, quietest running, and most fuel-efficient sport sedan we put under the gun. This Ford is a remarkable piece of engineering. As proof of the speed-with-spaciousness definition of a sport sedan alluded to earlier, the Taurus SHO runs to 60 mph in seven seconds, and it will top out at over 140 mph. If that isn't enough speed, you'll have to take either a sports coupe or a German sedan costing over \$50,000. Like all Tauruses, the SHO seats five comfortably. The front buckets are sporty in design and highly adjustable, but they lack a natural pocket that one can immediately settle into. Interior decor is purely functional: The tachometer is redlined at an impressive 7,000 rpm; the five-speed shifter (no automatic is offered) is as stout as a baseball bat; and the instrument panel is decorated with metallic-looking trim

Continued



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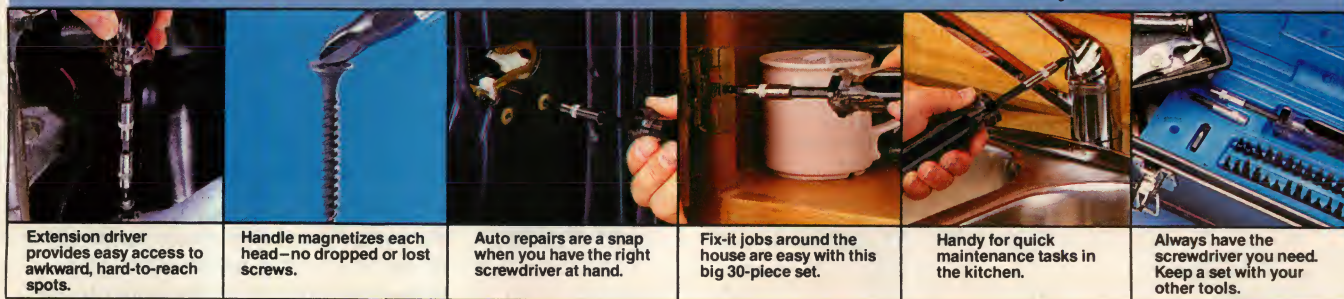
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Fast-track sedans *Continued*

POPULAR SCIENCE TEST RESULTS

TEST RESULTS	Audi 200	BMW 535i	Ford Taurus SHO	Nissan Maxima SE
Acceleration (sec.)				
0-30 mph	3.6	2.6	2.3	3.0
0-60 mph	8.9	7.3	7.0	8.7
Brake test, 60-0 mph				
Cold stopping distance (ft.)	136	116	152	154
Warm stopping distance (ft.)	133	132	129	153
Hot stopping distance (ft.)	133	133	141	159
Double-lane-change test (mph)	56.6	57.4	58.6	55.3
600-ft. slalom test (mph)	46.9	44.9	46.4	44.3
Road holding (g)	0.83	0.79	0.84	0.80
Interior noise (dBA)				
At idle	55	50	48	40
At 60 mph	70	66	70	69
EPA FUEL MILEAGE (mpg)				
Highway	22	23	34	26
City	18	15	21	20

Dimensions and specs

DIMENSIONS				
Wheelbase	105.6	108.7	106.0	104.3
Overall length	192.7	185.8	188.4	187.6
Overall width	71.4	68.9	70.8	69.3
Overall height	55.9	55.6	54.3	55.1
SPECIFICATIONS (as tested)				
Engine type	Turbocharged in-line 5	In-line 6	V6	V6
Displacement (cu. in./liters)	136/2.2	209/3.4	183/3.0	183/3.0
Compression ratio	7.8:1	9.0:1	9.8:1	9.0:1
Induction	EFI	EFI	EFI	EFI
Net horsepower @ rpm	162 @ 5,500	208 @ 5,700	220 @ 6,700	160 @ 5,200
Net torque (lb.-ft.) @ rpm	177 @ 3,000	225 @ 4,000	200 @ 4,800	181 @ 3,200
Transmission	3-speed automatic	5-speed manual	5-speed manual	5-speed manual
Final drive ratio	3.08:1	3.45:1	3.74:1	3.65:1
Steering	Power assist rack and pinion	Power assist recirculating ball	Power assist rack and pinion	Power assist rack and pinion
Turn diameter (ft.)	34.2	36.1	38.1	36.7
Front suspension	MacPherson strut with coil spring, stabilizer bar	MacPherson strut with coil spring, stabilizer bar	MacPherson strut with coil spring, stabilizer bar	MacPherson strut with coil spring, stabilizer bar
Rear suspension	Rigid beam axle with two trailing arms, coil spring, and stabilizer bar	Independent, semi trailing arm, coil spring, stabilizer bar	MacPherson strut with coil spring, two lateral links, one trailing link, and stabilizer bar	MacPherson strut with coil spring, two lateral links, one trailing link, and stabilizer bar
Brakes	Power assist disc, disc w/ABS	Power assist disc, disc w/ABS	Power assist disc, disc	Power assist disc, disc w/ABS
Curb weight (lbs.)	3,249	3,623	3,349	3,144
F/R weight distribution (%)	62/38	50/50	63/37	62/38
Fuel tank (gal.)	20.6	21.1	18.6	18.5
Trunk volume (cu. ft.)	16.7	16.2	17.0	14.5
Base price	\$33,005	\$43,600	\$19,739	\$18,099
Price as tested	\$35,555 ¹	\$45,225 ²	\$21,086 ³	\$19,549 ⁴
Major options (over \$100): ¹ Leather seats \$1,250, cold weather package \$500, pearlescent clear-coat metallic paint \$450, front sport seats \$350; ² gas-guzzler tax \$850, compact-disc changer \$775; ³ preferred equipment package \$533, dual six-way power seats \$251; ⁴ ABS brakes \$1,450				

instead of the simulated wood used in other Taurus.

Delivering 220 hairy horsepower to the pavement through the front wheels is no small task, and Ford's Taurus team deserves a gold star for making the SHO practically free of torque steer (a tendency to dart off-line when the throttle is floored), thereby killing the myth that 200 hp is the maximum power a front-drive car can handle. Although the car's basic suspension geometry wasn't disturbed, spring rates, shock-absorber valving, and pivot bushings were all substantially stiffened. As a result, the Taurus SHO is by far the firmest-riding car in this test, and that partially explains its excellent showing in the double-lane-change and slalom tests. The sacrifice (there always is one) is evident off the test track: Though the Taurus rides comfortably over smooth roads, it punishes its occupants over broken pavement and potholes.

The Taurus SHO's engine is an absolute joy to live with. The response to a jab of the throttle is quick and forceful at any rpm, and the noise from under the hood is stirring but not strident right up to the redline. In addition, the SHO is a balanced player, with a chassis always capable of handling what the engine dishes out. Two minor complaints: Shift effort is high and Ford does not yet offer anti-lock brakes in this car. (ABS is planned for the 1990 model year.)

Graceful benchmark

The BMW 535i is a fine reference car in this sport-sedan comparison because this is the latest effort from a firm acknowledged as the leader in the field. Amazingly, there is a wide as-

Continued

Track-test update

The POPULAR SCIENCE car-test team has revised the braking procedures used for this comparison and for all to follow. Instead of separate stopping-distance and pedal-pressure-based fade tests, we have combined the two. The results box will now list stopping distances from 60 mph to reflect three different situations. The "cold brakes" result is analogous to a panic stop wherein the brakes have not been warmed to optimal operating temperature. The "warm brakes" result is identical to stopping distances presented in the past; that is, the shortest distance in which any given car can stop repetitively. The "hot brakes" result depicts stopping performance after two 60-to-0-mph brake applications with no intermediary cool down. If a car's brake system is prone to fade, a longer stopping distance will be revealed by the third result. As before, these results depict the minimum attainable stopping distances without locking the brakes and skidding the tires.—D. S.

Parts and service

PART PRICES (manufacturer's suggested retail)				
Brake pads, front	\$145	\$129	\$ 48	\$ 56
Brake pads/linings, rear	85	87	58	36
Front shock/strut insert	104	194	68	222
Alternator	277	483	233	230
Fuel pump	182	263	118	213
Ignition module	n.a.*	1,125	69	595
Grille	94	110	n.a.	107
Front bumper	354	423	288	163
Windshield	562	411	565	615
Taillight lens	88	141	49	13

*not available

PS serviceability ratings

Checking oil level	5	5	5	5
Checking coolant level	5	5	5	5
Adding oil	5	5	5	5
Changing oil filter	4	4	4	3
Changing spark plugs	3	4	2	4
Changing belts	3	3	2	3
Changing radiator hoses	3	3	3	3
Changing heater hoses	3	3	3	3
Checking fuses	4	4	3	4
Spare-tire access	4	4	4	4

(Ease of service: 5 = excellent, 1 = poor)

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Fast-track sedans *Continued*

sortment of supposedly obsolete components under the new-for-'89 535i: items mentioned earlier plus recirculating-ball steering, a MacPherson-strut front suspension, and a semi-trailing-arm rear suspension at the expense of rack-and-pinion steering and multi-link suspensions. Yet the 535i is a model of grace and refinement. Its engine is powerful and smoother than a kitchen blender, all the way to the 6,300-rpm redline. The cockpit layout is just about perfect, and ride motions are fluid at any speed.

The key word here is refinement. It's as if a vast platoon of BMW engineers toiled over this car for years to hone its every edge to a brilliant finish. (In fact, the development process lasted six years.) BMW accomplished many improvements with this new model, in comparison with its predecessor. The new 535i is bigger and therefore roomier, aerodynamic drag is substantially lower, and the body structure's torsional stiffness is some 70 percent higher. The center of gravity is two inches lower, and weight distribution is virtually 50/50 thanks to such measures as rear-mounted battery. Although the curb weight is higher by 260 pounds, there's also a 14-percent increase in horsepower, to 208 hp at 5,700 rpm.

Although the \$45,000 535i scores only a close second to the \$21,000 Taurus on the track, the two are worlds apart over the road. Like the Ford, the BMW responds smartly to a jab of the throttle; both top out on the far side of

140 mph. The difference is that the Ford transports you in a steely fist while the BMW cradles you in kid gloves.

The 535i, like any car, has a few drawbacks. The center position in the rear seat is not comfortable for adults and the trunk is the smallest of the test cars; both shortcomings are largely due to the car's rear-drive layout. The BMW wags its tail some in the double-lane-change test, as you'd expect of a rear-driver with balanced weight distribution. Last, the BMW's Pirelli P600 225/60VR15 tires weren't particularly grippy in hard cornering.

Maximum Maxima

The Nissan Maxima represents Japan's boldest attack on the U.S. large-car market to date. While this new-for-'89 model is in a bit over its head in this group (it finished at or near the bottom in most test-track categories), POPULAR SCIENCE testers found it to be a pleasant car to drive and one that's impressive in many areas. The Maxima is remarkably roomy. It is powered by a smooth V6 engine and finished in the German rather than the Japanese idiom, with function as the top priority and devoid of flashiness both inside and out. My favorite detail is the marking used for speedometer and tachometer dials. Rather than the commonplace white lettering on a black background, Nissan has selected the reverse: In daylight you see black numerals on a white field. At night, the instruments magically reverse to white

markings on a dark field—thanks to electroluminescent light sources that outline the numbers and needles on the dials.

The Maxima has a few drawbacks that limit its dynamic poise. The Bridgestone P205/65R15 all-season tires aren't very sticky. And at times there is excessive understeer, in which the front tires lose their grip long before the rears. In the slalom and double-lane-change tests, the Maxima flopped over on its suspension stops as if it were weak in the knees, a result of inadequate roll stiffness and damping. Considering that we tested the sporty SE version of the Maxima (the car is also available in more sumptuous GXE trim), I feel that suspension settings should be firmed up.

Teutonic turbo

The Audi 200 was hampered in acceleration tests by its automatic transmission (a five-speed is available—at a \$550 savings). Furthermore, a 2.2-liter engine—even with turbocharging—is no longer gutsy enough to play the sport-sedan game in convincing fashion, particularly when the price tag runs well over \$30,000. The upgrade I'd recommend is switching to the 2.3-liter 20-valve engine, which Audi will soon introduce with the 1990 Quattro Coupe.

In every other respect the Audi 200 is satisfying. It led the field in agility on our slalom course and demonstrated excellent grip in hard cornering. The new instrument panel is properly endowed with large, easy-to-read analog dials, and a tasteful band of zebrano wood molding runs across the instrument panel and doors and down the center console. An Auto Check computer monitors 10 critical vehicle functions. The chair-high seats are form-fitting and comfortable, though the rear seat's usefulness is diminished by a large center hump on the floor. Even though the Audi 200's exterior design is now six years old, it is still clean and contemporary looking.

After the dust had settled and the data was reduced, the POPULAR SCIENCE test team concluded that there are no losers in this field. The BMW 535i is one of the most highly refined rear-drive sedans ever to roll down the pike. The Nissan Maxima SE is a portent of even greater things to come from Japan. The Audi 200 is a model of poise and polish.

The clear winner, however, particularly when its price is considered, is the Ford Taurus SHO. That the United States has introduced a world-class sport sedan that can knock heads with the best of them—and win—should give us all cause for celebration. **P.S.**

Two big surprises

When we decided to pit Ford's Taurus SHO against some of the finest European and Japanese sedans, Ford seemed to be trying an automotive replay of G. B. Shaw's *Pygmalion*, passing off its plain-Jane Taurus as high society—a car that, after all, is a basic intermediate sedan with a high-output engine.

The first surprise came at the test track, where the SHO's 220-hp high-output V6 simply walked away from the competition, one of which costs twice as much. Aside from the raw power it punches out, the Yamaha-built SHO V6 is tractable, smooth, and responsive in day-to-day driving. The performance modifications to the suspension make it easier to steer in the real world, and at the same time soften the traditional Taurus understeer. The ride is quiet and firm; the brakes, superb. Only a few drawbacks, mainly a notchy gearbox and middling interior treatment, distinguish this car from the upper reaches of luxury sedans.

All of this means that BMW can't rest easy, but can still be assured that it makes the definitive performance sedan. The new 535i swings the sport-sedan equation more to the sedan side of the hyphen; the result is a smoother package that is less tail-happy in the

corners. You ought to get something for 45 grand, and you do; the exceptional level of refinement and quick response are noticeable.

The second big surprise came from Nissan, which has gone from bug to butterfly in a single leap with the new Maxima. The car's relatively low-rated horsepower kept it out of the performance league of the Ford and BMW, but the overall package benefits from a stiffened body structure, effective rear suspension, and an outstanding gearbox. At a dollar-per-feature category, the Maxima is nearly the equal of the Taurus.

The new Audi 200 still suffers from the low-displacement blahs, pumped up only mildly by the turbo. On the other hand, it is still a well-executed sedan that has an immeasurable sense of design integrity, with the best interior comfort of the group. As with the BMW, the main problem is justifying subtle engineering refinements against crude increments in cost.

Although I would pick the Taurus SHO as the best value of the lot and the BMW 535i as best overall, it would have to be a forced choice. All of the cars performed admirably, and the combination of luxury features and performance muscle should satisfy the whims of any Beverly Hills parking attendant.

What more could you ask?—*Dan McCosh*

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Looking Back...

Sampling a century of POPULAR SCIENCE

100 YEARS AGO MARCH 1889

"The great question still remains to be answered," wrote Ira Remsen, professor of chemistry at Johns Hopkins University: "What is an element? It is true we call them elements, meaning by that substances which cannot be converted into anything simpler.

"These so-called elements are shown to be related to one another, and it seems impossible, in the light of these facts, to believe that they are distinct forms of matter. It seems much more probable that the nearly seventy elements are in turn composed of two subtler fundamental elements combined in different proportions. There does not, however, appear to be any immediate prospect of discovering these fundamental substances."

But Remsen did predict the discovery of more elements (there are now

103 in the periodic table). To him it was a patriotic pursuit: "Let us hope that the next element may come to light in the New World, and that we may thus have our own particular element, as France and Norway and Germany have theirs."

50 YEARS AGO MARCH 1939

"By 'chopping time up into small bits and freezing it,' a new ultraspeed lamp for photographers produced this remarkable picture of a golfer striking a ball. Successive images, made on the same film at the rate of 600 a second with a $\frac{1}{100,000}$ -second flash reveal the progress of the swing from the top of the stroke to the end of the follow-through."

Harold E. Edgerton of the Massachusetts Institute of Technology later used



his ultrafast flash camera to capture on film bullets traveling through apples at 2,800 feet per second and other previously invisible phenomena.

25 YEARS AGO MARCH 1964

Car phones, cordless phones, and cellular phones are the modern way for telephone addicts to obtain their fix. But in the annals of POPULAR SCIENCE we've found the possible precursor to this phone-away-from-home trend. "Active people who have to be away from their desks much of the time can carry a phone extension in the shirt pocket with this remote unit. The Pocketfone has a range of up to two miles and buzzes when the user's telephone rings. Back at the desk, a fixed stand holds the phone, and a cradle raises and lowers the receiver." For \$5 to \$15 a month, the "man on the go" could lease this equipment. With a two-mile limit, the Pocketfone was perfect for trips to the corner store.



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The following introduces one of the most fully tested and credentialed gas saving, friction reducing engine treatments ever to reach the market!

WHAT IS POLY? "Poly" is short for polytetrafluoroethylene (TFE). It is the slipperiest substance known to man. **The 1988 Guinness Book of World Records (pg. 182) says:** "The lowest coefficient of static and dynamic friction of any solid is 0.02, in the case of Polytetrafluoroethylene -equivalent to wet ice on ice. It was first manufactured in quantity by E.I. duPont in 1943, and is marketed as Teflon."

The PetroLon Corporation, makers of Slick 50, have invented a way to permanently bind this slippery chemical to your engine with one treatment. All you do is add one quart of Slick 50 to your oil during oil and filter change. By reducing engine friction, Slick 50 increases gas mileage and horsepower and reduces engine operating temperature thus causing your oil and engine to last longer. Just as important, it reduces metal wear, defraying costly overhauls.

Slick 50's credentials are impressive.

"Slick 50 does reduce engine heat and ordinary wear, and our informal tests indicate that it will improve gas mileage by about two or three miles per gallon...Slick 50 does exactly what PetroLon claims it does." Consumers Digest, (March/April 1982, p. 35)

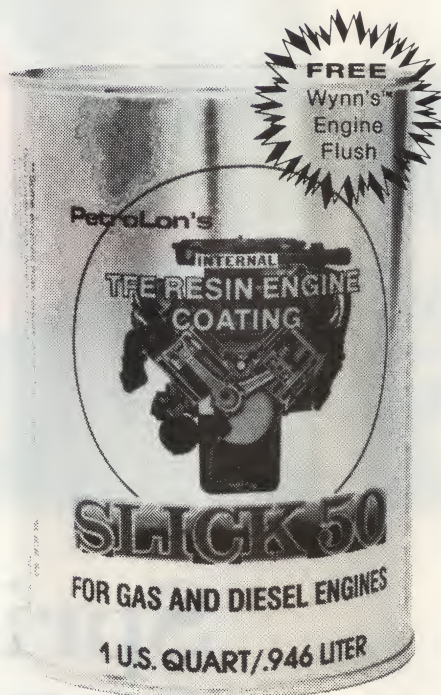
Researchers at a **nationally respected research laboratory**, after applying a powerful ultrasonic cleaning process to a Slick 50 treated engine part, were surprised at its permanence. They stated, "We actually expected the PetroLon Slick 50 'Poly' resin coating to also be removed, but later found it was still there."

The Federal Aviation Administration has fully accepted a similar product—Slick 50 Aircraft Treatment (F.A.R. #33.49).

TUV, a German testing laboratory with credentials every bit as prestigious as our Underwriters Laboratories, tested Slick 50 in 1986. They found substantial increases in both gas mileage and horsepower. Their tests showed that these gains were due to a reduction in friction.

A test done at the **San Diego State University** revealed that, "Slick 50 does increase horsepower and decreases fuel consumption in tests done at the university." The **Space Shuttle Columbia** uses the chemical "poly" in its gears and bearings because it is the only chemical lubricant which can withstand the heat and corrosive elements of space.

Perhaps the most dramatic of all is a torture test overseen by the Automotive Services Council for Pennsylvania. This test was shown on television station WTVE: Three cars with between 75,000 and 129,000 miles on them, were treated with Slick 50. Six months later the oil was drained from each vehicle and the cars were driven without the oil plugs for about half an hour. The water temperature never rose and the engines sustained no apparent damage.



How do you give an engine a "poly" treatment? Very simply! Just before an oil and filter change, add Wynn's™ Engine Flush (sent **free with each order**) to clean out your engine. Then drain your oil, change the filter, and add the proper amount of oil less one quart. Add one quart of Slick 50, drive for thirty minutes, and leave it in the crankcase for 3,000 miles. (Add two quarts for engines with oil capacities of seven quarts or more.)

Slick 50 gives a permanent coating so you need to treat your engine only once, and not each time you change your oil. Slick 50 is also excellent for turbocharged engines, aluminum block engines and rotary engines.

Will it work with most oil? Yes! Slick 50 will work with all petroleum-based oils and synthetics compatible with petroleum based oils.

What are the benefits of Slick 50? Your actual benefits in percentages may vary, depending on the kind of driving you do, the condition of your vehicle, etc. By reducing friction, Slick 50 does all of the following: Slick 50 **increases gas mileage**. Slick 50 **increases horsepower** - small economy cars and large RV's really need this! Slick 50 **makes for easier starting** (important in cold weather.) Slick 50 **reduces operating temperatures**, thus increasing the lubrication of your oil and the life of your engine. Since lubricating lead is being removed from gas, and unleaded gas is poor in lubricating qualities, **this extra lubrication of Slick 50 on valve systems and guides is a real bonus.**

Last, but not least, the drastic reduction in engine wear can delay costly overhauls. These can often cost well over \$1,000. Slick 50 eliminates the "lubrication starvation" that all cars experience when you first start them, before the oil has a chance

to circulate. Up to 90% of the wear on a car can be caused by this lubrication starvation. You receive all these benefits for less than the cost of two tanks of gas (\$39.95).

Will Slick 50 harm my engine or affect my warranty? No! Slick 50 is suspended in an excellent grade of petroleum oil which meets, or exceeds, every manufacturer's engine warranty requirements. In addition, this oil carries an API (American Petroleum Institute) service classification SF-CC-CD.

More Slick 50 products are available. These include Gear Treatment (manual transmission, etc.) 2-Cycle Engine Treatment, Grease, Fuel Conditioner, and Power Boost. Free information sent on request.

DOUBLE GUARANTEE!

Guaranteed lowest price and guaranteed satisfaction. If at the time of purchase you have seen Slick 50 advertised in a current magazine at a lower price, we will beat that price by \$2.00 a quart and you will still get your free engine flush. If you are not satisfied with our Slick 50, within 4 months, send us a note and proof of purchase for a full refund of purchase price. This makes trying Slick 50 **RISK FREE** to you. We have been in business for 10 years and intend to keep our customers happy.

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Spring '89 YARD POWER

As the days get longer and the sun shines warmer, the outdoors—and your yard and garden—beckons. The editors of *POPULAR SCIENCE* select the newest equipment to make working outside easier and more enjoyable.

By TIMOTHY O. BAKKE



▲ Super-maneuverable mowers

Riding mowers are virtual necessities for large lawns, but they can become a liability when it comes to trimming around trees and such. Hence a new generation of riders that are more maneuverable than ever (clockwise from left): the 14-horsepower John Deere F510 (or 17-hp F525); 12-hp Husqvarna 850-12; and 12-hp (or 16-hp) Toro HMR—Highly Maneuverable Rider. Perhaps most unusual is the mower from Husqvarna. With a cutting width

of 34 inches, it uses two separate frames, front and rear, connected by a pivoting joint to give it a turning radius of $3\frac{1}{2}$ inches. The HMR mows a 38-inch swath and boasts a turning radius of four inches, by virtue of the front wheels' 80-degree turning angle. The three-wheeled John Deere's pivoting rear wheel affords it a seven-inch turning radius; it has a cutting width of 38 inches. Prices: F-510 (\$3,999); 850-12 (\$2,495); 12-hp HMR (\$3,199).



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—Chuck Yeager

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Spring '89 YARD POWER

Circular sickle bar ►

At first glance, the RedMax Reciprocator trimmer looks like any other weed cutter/brush saw—a long shaft with a small (15.5-cc) two-cycle engine on one end and a circular cutter at the other. But a closer look reveals a cutting head (detail) made of two 20-toothed blades mounted face to face that pivot back and forth in opposite directions. In *POPULAR SCIENCE* tests, the reciprocating action resulted in a fast shearing cut, and the trimmer didn't spew debris in all directions as other cutters do. Also, the Reciprocator cut brush up to ½ inch thick while demonstrating some safety advantages: It doesn't kick back and has less ability to inflict a serious wound than conventional brush cutters. Cold starts, however, often took six to eight pulls, and the kill switch is hard to reach. Price: \$499. RedMax, Box 1545, Norcross, Ga. 30091-1545.



◀ Disinfecting pruner

The KlipKleen pruner was developed to extend the function of pruning shears. Through a patented fluid-delivery technology, surface disinfectants, propagating agents, herbicides, growth retardants, and systemic insecticides can be applied where they are needed at the same time a branch is cut for pruning. Pruning system: \$25; adapter kit (using your own shears): \$13. Bloomland Special Products, Box 95363, Atlanta, Ga. 30347-0363.



Tight-turning tractor ▲

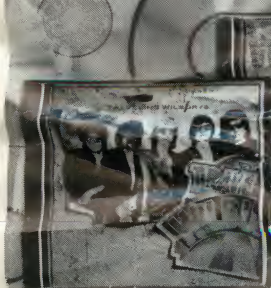
Four-wheel steering on the 12-hp Noma 4012-01 lawn tractor gives you a turning radius of just 12 inches at a low price: \$1,499 to \$1,699. Other features: shift-on-the-go eight-speed transmission and 40-inch twin-blade mower deck. Noma Outdoor Products, Box 7000, Jackson, Tenn. 38308-7000.

◀ Plastic-nose tractor

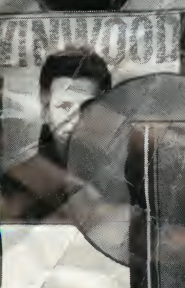
With its hood, grille cover, and side panels made from General Electric Noryl GTX resin, this 18-hp twin-cylinder yard tractor tops off the new Sentar line. A monitor system displays clutch, reverse-gear, and power-takeoff engagement. Standard equipment includes a hydrostatic transmission and a 46-inch mower deck. Sentar Power Equipment, Box 360900, Cleveland, Ohio 44136; \$2,700.



DISCS, DISCS, DISCS, DISCS!



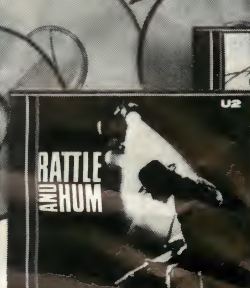
The Traveling Wilburys—
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Masterworks) 373548
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Diane Schuur—Talkin'
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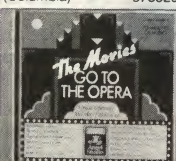
Journey's Greatest
Hits (Columbia) 375279



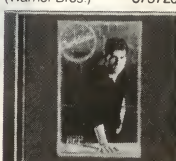
Guns N' Roses—Appetite
For Destruction. (Geffen)
359984



Kenny G—Silhouette.
(Arista) 371559



The Movies Go To The
Opera—Various Artists.
(Angel Studio) 372342



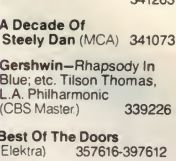
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Spring '89 YARD POWER



Pro-quality lightweight ▲

Weighing only 11 pounds with a 35-cc engine, the McCulloch Titan 35 vertical-engine chain saw sports such high-end features as a chrome cylinder bore, gear-driven automatic oiler, and electronic ignition. McCulloch Corp., Box 92180, Los Angeles, Calif. 90009; \$300.



Carry-all plastic cart ▲

With its 20-inch wheels, six-bushel high-density-polyethylene tub, and low center of gravity, the Carry-It cart is designed to make tough hauling jobs easier, says its maker. The 5/8-inch steel axle is welded to a three-inch-wide full-width steel plate, and the \$150 cart, which weighs 40 pounds, can carry 300 pounds, claims Kadco, Inc. (9 Granger Ave., Saratoga Springs, N.Y. 12866).



High-capacity bagger ▲

Quadbagger's four plastic containers hold 13 bushels of debris. Fed by a mower-driven collection fan with a see-through chute and covered by an elasticized fabric cover, the containers are mounted in a steel cart. For use on 4200, 5200, and 6500 Series tractors, the system costs \$790. Simplicity Manufacturing, Port Washington, Wis. 53074.

◀ Vacuum with a cart

Slip a plastic trash bag into the cart and hook up the Yardcleaner vacuum; you're ready to clean up a 16-foot circular area.

The blower-vac has a nine-ampere electric motor; a wraparound handle, with palm grip for vacuuming; and a suction tube that tapers out to prevent clogging. Black & Decker, Box 798, Hunt Valley, Md. 21030-0748; \$74 (blower-vac), \$50 (cart), \$108 (vac-cart).



"Turbocharged" chain saw ▶

The 2051's "turbo" effect is the result of the saw's new air-filtering system in which air is forced into the combustion chamber. Also, fuel-mix setting, rev limiter, and ignition setting are micro-processor-controlled. Jonsered, Box 68, Rye, N.H. 03870; about \$350.



Two-cycle mower ▲

The 140-cc two-cycle engine on the Echo LM-212P lawn mower puts out 4.1 hp and uses the zone-start safety system; the self-propelling transmission is gear-driven. In POPULAR SCIENCE tests, the mower started easily and was pleasant to use, but it bogged down in tall (six-inch) grass, and the three-bushel catcher clogged easily. Echo, 400 Oakwood Rd., Lake Zurich, Ill. 60047; \$580.



Lightweight hedge trimmer ▲

The nine-pound HT-17 trimmer with coil-spring isolation system provides the cordless convenience of a gas tool without the weight and vibration, says Homelite (14401 Carowinds Blvd., Charlotte, N.C. 28241). \$150.

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New suspenders

Chassis innovations improve motorcycle handling and ease maintenance.

By STUART F. BROWN

BMW R100GS

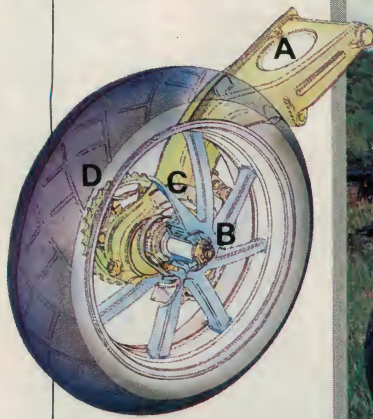


BMW's Paralever suspension carries the double-universal-jointed drive shaft (A) in a stout swing arm (B). An additional strut (C) anchors the lower part of the rear-drive housing to the bike's frame, preventing the swing arm from reacting to changes in throttle setting.

PHOTOS BY GREG SHARKO

HONDA HAWK GT

Honda's Pro-Arm rear suspension uses a hefty cast-aluminum arm (A) that supports the rear wheel from the left side. A single nut (B) holds the wheel in place. When the wheel is removed, the rear disc brake (C), sprocket (D), and drive chain remain undisturbed. An eccentric hub design allows for quick adjustment of chain tension.



From one side, both of these motorcycles share a peculiar attribute: It looks as if there's nothing connecting the rear wheel to the rest of the bike. That's what a single-sided rear suspension looks like from the non-business side. In addition to provoking comments from curb-side observers, it's a feature that makes it a lot easier to fix a flat tire.

This advanced kind of suspension is found on two bikes from BMW and Honda that incorporate fresh thinking in chassis design into machines that are capable in more roles than one.

In the go-anywhere R100GS, BMW has mated the latest 1,000-cc version of its venerable flat twin engine with a long-travel suspension to create a 412-pound bike that's agile and decidedly pleasant to ride on the highway. At the same time, it's ready to take you miles away from civilization with no worries about running out of fuel. The big gas tank holds nearly seven gallons.

A clever element in the BMW's rear suspension design (drawing) subdues a quirk inherent in shaft-drive motorcycles: Normally when the rider opens the throttle, a torque reaction at the housing enclosing the ring and pinion gears causes the rear suspension to extend. This "shaft jacking" makes the rear of the bike rise and fall, adding unasked-for complexity to the dynamic forces already generated by braking and leaning into turns. The \$6,150 R100GS has this problem effectively licked (see caption).

Honda's Hawk GT houses a high-torque 647-cc liquid-cooled V-twin engine in a chassis like those found in Grand Prix racing bikes. The aluminum frame uses a massive main member that runs diagonally from the steering head down to the pivot point for the rear suspension. The single-sided suspension arm (drawing) combines with the frame to form a strong and lightweight chassis, giving the Hawk stable yet responsive handling.

Excellent brakes and fat tires contribute to this 393-pound machine's superb manners on twisty roads, but the bike is just as pleasant to ride to work or on a weekend trip. I particularly like that Honda didn't hide all the beautifully crafted bits and pieces behind a fairing. The \$4,198 Hawk GT is an up-to-date incarnation of those uncomplicated bikes that provided lots of fun in the 1960s and '70s. **D**

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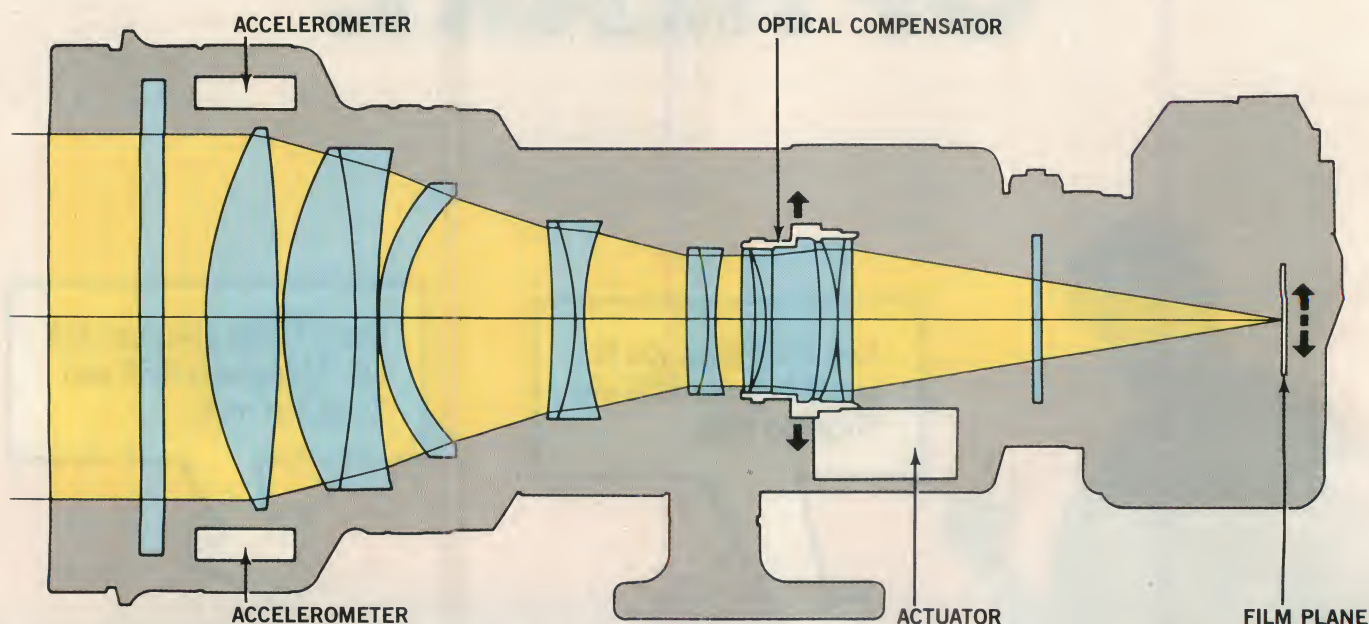
Have you driven the first all-new full-size pickup introduced in this decade? Maybe it's time you gassed up your Ford and took a look. At your Chevy dealer's.

Comparisons based on data available at time of publishing.
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No-shake telephoto



PHOTOS BY BURT PLOTKIN

A prototype image stabilizer built into long lenses could eliminate the last of the point-and-shoot problems.

By ARTHUR FISHER

The entertainment business still shelters some unreconstructed male chauvinist pigs who refer to something called the "jiggle factor" as an additive that can boost ratings. For those who have never seen such television shows as "Three's Company" and its like, the factor referred to rises exponentially with the show's quota of well-endowed young women whose motions are vigorous and unconfined.

Oddly enough, just such performers were employed by Canon at a giant product expo last year to introduce a device that will counteract jiggle—the photographic jiggle that can mar photographs by blurring them, especially when the photographer is attempting to hand-hold a camera with a long lens at a slow shutter speed. The device is an image stabilizer built into a 300mm telephoto lens.

"Camera shake is the last remaining obstacle to true point-and-shoot photography now that auto-exposure and auto-focusing are here to stay,"



The photo at right was taken with a 300mm lens hand-held at $\frac{1}{60}$ second. The photo at left, made with the cam-



era on a tripod, simulates the use of an image-stabilized lens. The cutaway shows optomechanical elements.

explained Canon technical national manager David R. Metz as he steered visitors through the crowded, carnival-like exhibits to the stabilizer display. There, two EOS single-lens-reflex cameras, each equipped with a 300mm lens, were aimed in parallel at a trio of aerobic dancers who were bouncing hither and yon. One lens had the stabilizer, one didn't. When both were jigged, the image in the viewfinder of the stabilized camera remained steady; the other rocked visibly.

The stabilizing system uses a set of accelerometers that sense motion in any direction. They command an actuator, which in turn operates an optical compensator—actually a group of four movable lenses—to cancel out the

motion. The whole optomechanical feedback system is lighter and more compact than similar systems in movie cameras and camcorders. In fact, the two lenses looked identical; the stabilized lens was imperceptibly larger and heavier.

Canon designers claim the device will allow shake-free photography with a hand-held 300mm lens at a slow $\frac{1}{60}$ second, rather than the $\frac{1}{250}$ to $\frac{1}{500}$ second most photographers would opt for.

The stabilizer will probably first be available in telephoto lenses; when, and at what price, Canon executives have not yet determined. Eventually, it should appear in true point-and-shoot cameras that compensate for jiggle. **PS**

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So don't blow it. Get to your Cub Cadet dealer before April 1, and bag yourself a Cub Cadet 1720 with 46" deck at a super price!

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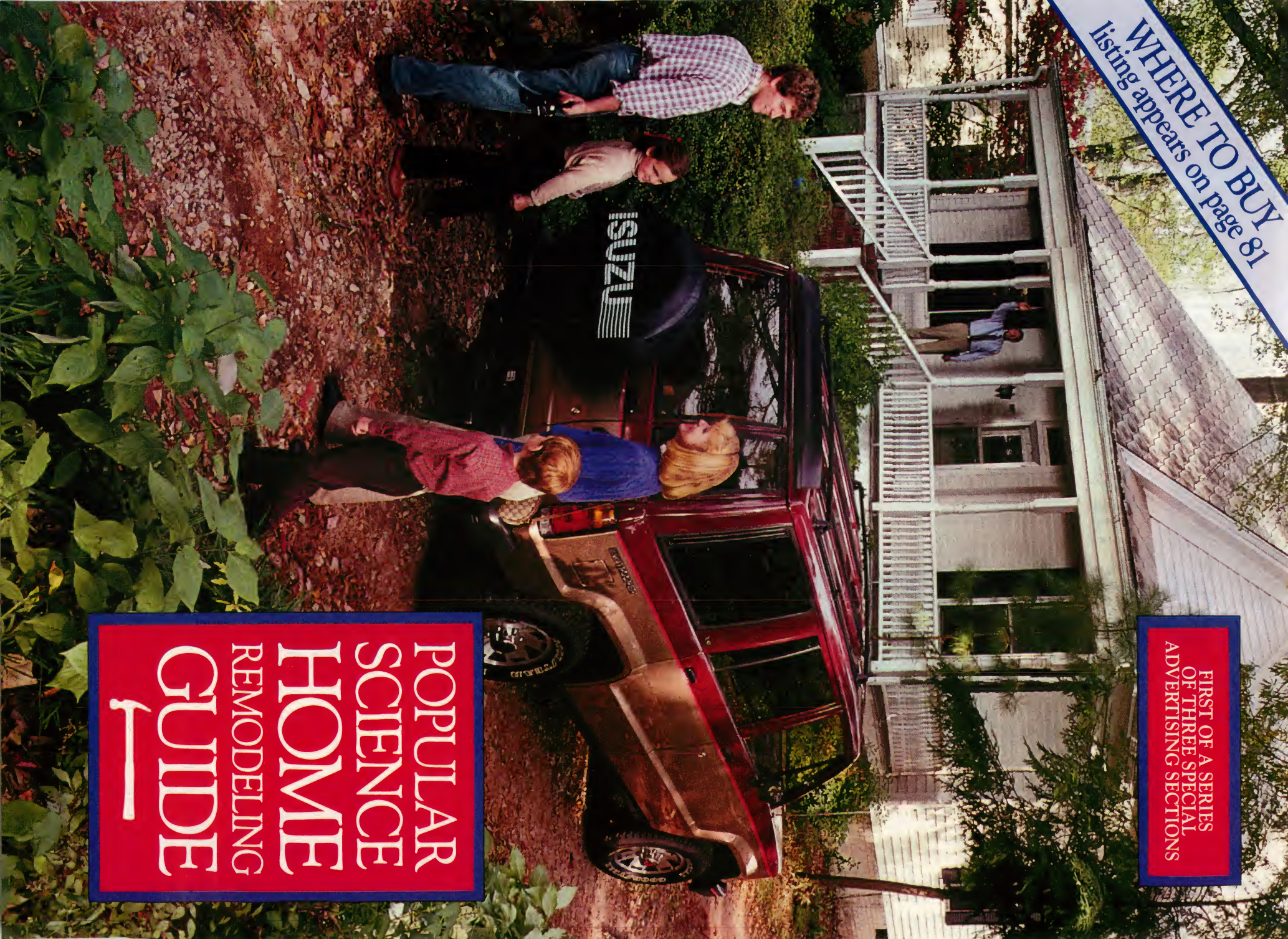


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WHERE TO BUY
listing appears on page 81

FIRST OF A SERIES
OF THREE SPECIAL
ADVERTISING SECTIONS

POPULAR SCIENCE HOME REMODELING GUIDE



Home Remodeling: Planning and Preparation



As you read the *Popular Science* HOME REMODELING GUIDE, the actual experience of remodeling an older home will unfold before you. This series of three special sections will follow the ongoing renovation process of a home that features quality products and services supplied by advertisers who want American homeowners to learn more about them.

In developing the series, we purchased a home in Madison, Georgia and went through the steps a family would take to remodel that home completely. This first section deals with planning and preparation, up to the beginning of the actual work.

Subjects:

- Thinking, planning, making basic decisions
- Building "sweat equity"
- Preparing yourself for remodeling
- Your present home or a move?
- The professionals: Real estate brokers, appraisers, inspectors, construction workers and supervisors, lawyers, etc.
- Our location: Madison, Georgia
- Planning and looking

- Inspecting for structural problems
- Making an offer to buy
- How to shop for mortgage money
- Home equity loans
- The closing, how to cover yourself, what happens
- Homeowner's insurance
- Getting started and what's ahead

- Special features about leading manufacturers' products and services
- We are bringing this guide to you to give you a better idea of the manner in which many American families are improving their lifestyles by remodeling. There will be frustrations, and there will be triumphs. We'll report both.

Making Basic Decisions About Remodeling

Weigh the costs of fixing up an older home versus the increasing costs of new homes and you'll see that remodeling is often an extremely good option.

You can cut down on costly mistakes and have a better finished job if you think carefully about the house and exactly what it is that you want to change. Plan ahead before making any basic decisions. You may want more living space; a more energy-efficient house; improved appearance; modernized kitchen or bathrooms; improved heating, cooling, plumbing or electrical systems; or simply to add amenities. Make sure that your expenditures are good investments in resale value.

About the Front Cover

In the photograph on the cover, a house-hunting family visits the older home which is the subject of the three-part remodeling case history that starts this month, with follow-up features in April and June. You could win the remodeled house featured in these sections or \$100,000 in cash! Turn to page 81 for further details about the WIN THIS HOUSE SWEEPSTAKES which runs from March 1—July 31, 1989.

Or you might win First Prize: a roomy Isuzu Trooper like the one shown in the driveway; or Second Prize, a rugged Isuzu Pickup. The 'Trooper' has even more room (71 cubic feet) with the back seat folded up. Automatic transmission and 2-door body style are available. Models are wearing Georgia Boots™ and pants by Dickies™.

Be especially careful about changing the character of an older home. Some "improvements" actually result in damage to the personality of the original structure. Others, thoughtfully executed, can add value and make the house far more livable, while still keeping its basic integrity.

When in doubt, get expert help from an area architect, designer, real estate broker or agent, builder, contractor or other helpful, knowledgeable individual or organization.

For our project, we were fortunate to have the services of a nationally known architectural design firm, Van der Cleveland Design Consultants, Ltd., of Atlanta, plus the tremendous assistance of many participating manufacturers.

Equity and "Sweat Equity"

Making the monthly mortgage payment is a gradual method of increasing your equity in a home. More equity is usually gained faster by the appreciation in value of a home, which can occur as long as it is kept in good shape and is not in a depreciating neighborhood. There are dangers such as fire, flood or tornadoes, but you can insure against most such threats. Over the years, the traditional inflationary trends in residential housing have made home ownership one of the best and safest investments that the average American can find.

There's still another way of increasing the value of your investment and that's through "sweat equity," or exchanging your time and labor for added home value. Many people gain major financial advantages, as well as personal satisfaction and psychological benefits, by fixing up older homes in desirable locations. When in truly bad shape, such a home falls into the advertised or listed category of a "handyman's special" and may often be picked up at a big discount from its relative potential price when location, size and other factors are considered.

If you're willing to invest your own time, some remodeling projects will require only modest expenditures for tools and materials. Determine for yourself what you can and cannot do but, when making a final decision, consider the personal pride that comes from doing it yourself.

Your Own Older Home Or a Move?

The obvious first solution for a homeowner wanting more space, more comfort or a more energy-efficient home is to choose to remodel the present dwelling.

Sometimes that is impossible, impractical or undesirable. The neighborhood may have gone through a negative transition. Or the family may have changed in size. The financial situation may warrant a better home, or a lesser one. At times, the family needs a change because of schools, jobs, friends or other personal considerations. Relocation to a new geographic location may be dictated by



Handy Househunting Kit

A basic "search kit" will be a real help if you're inspecting a lot of homes. You'll want to peer into dark spaces, pry around, make measurements, and then remember as much as possible, so a powerful Mag® flashlight, easy-to-use measuring tape by Lufkin®, screwdriver, pencil and notebook will be very useful. Photograph everything with an Olympus® Infinity Super Zoom 300, a totally automatic camera with built-in 38-105 mm zoom lens. Pack your kit in a belt with Prolite™ pouches by Nicholas, made of Cordura® Plus, a high-density fabric designed by DuPont and McGuire-Nicholas.

Preparing Yourself for Remodeling

Are you psychologically prepared for the stress that remodeling a home can bring to you and your family? Remodeling problems have brought about many laughs in movies and television but, somehow when your own family is involved, they can be serious.

You and your family will have to take a realistic approach to remodeling, with everyone aware that routines will be interrupted. Even the simplest tasks will demand substantial time. Ideally, you can employ a professional contractor to do the major projects before you move in or while you're on vacation. If that's not feasible, perhaps you can do it yourself at your own pace and without outsiders. For most people, the hardest route is to employ strangers. They seem to roam at will about the house and are constantly underfoot, ripping out familiar features and installing strange new layouts, products and materials.

Many families who have been through a stressful remodeling agree that the wife makes the major adjustments, because bathrooms and kitchens are the rooms most frequently and extensively renovated, producing major interruptions in normal housekeeping routines.

Remodeling can definitely be a source of pride, particularly if you're able to do it yourself. You're making a statement to your neighbors and your community about how much you care about your family and your home. But what can you do to avoid or at least minimize stress?

Start by planning ahead. Visit your local library: There are excellent books and magazine articles on the subject and you can learn from the experiences of others. Ask friends, neighbors, retailers, Realtors®, contractors and other professionals for their advice. Write manufacturers for helpful literature. Take your time and spread out the projects. Plan thoroughly so that you won't be constantly changing your mind. Concentrate on doing things right even if it means delays, extra time and a bit more money. However, be flexible and make mental allowances for some revisions as you go.

Most importantly, do only those things you're comfortable with and that you're capable of doing. The fees you pay for professional assistance are good investments in both your comfort and your future. Once you're ready to hire a professional, ask questions and talk frankly with him about time and financial arrangements to avoid later surprises. Get all arrangements in writing, but expect some cost overruns. They just happen. Above all, take your time. It's your family and your home.

GET IT IN WRITING

How a little window shopping can save you \$500.

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MODEL DESCRIPTION	STANDARD PICKUP
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TOTAL \$7548	

EPA estimated CITY MPG 22	Gas Mileage Information	EPA estimate HIGHWAY MPG 24
Use estimated EPA figures for comparison. Your mileage may vary due to speed, weather, trip length and road conditions. Actual highway mileage will probably be less.		

If you don't look at an Isuzu when you're looking for a pickup, you could miss out on quite a lot.

Because for just \$7548*, the Isuzu pickup comes complete with every one of the standard features you see listed on this sticker. Everything from five-speed transmission to halogen headlamps.

Even though the Toyota has a higher base price, it only comes with some of these standards. And once it's equipped with all these features, the Toyota would end up costing you over \$500 more than the Isuzu.

But it still wouldn't be as good a pickup. Because Isuzu gives you a bigger payload, better mileage and more leg and shoulder room than Toyota.

So before you buy a pickup, look in our window. Otherwise you may be throwing your money out of one.

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The Isuzu Trooper is the Perfect Family Vehicle.

That's because the Trooper is both practical and handsome. The family's Isuzu Trooper drew approving looks while it was parked on the town square in Madison, just outside the Baldwin Realty office, as our Realtor®, Mike Bracewell, reviewed possibilities from the local Multiple Listing Service. He finally suggested the house we bought, just across the street from his own handsomely renovated home. The family is wearing Georgia® Boots and go-anywhere clothes by Dickies.

Stylish and comfortable, the Isuzu Trooper can shine brightly at the country club dance. Or, in its workaday role, its 71 cubic feet of space will handle dozens of hauling needs with ease. Four door convenience makes loading and unloading easier. Shift into 4-wheel drive and its fuel-injected 2.6 liter engine will handle the extremes of muddy sites, off-road locations and icy roads. Shift back into 2-wheel drive and it'll eagerly take you over long stretches of interstate highways or through cramped parking lots to the supermarket, hardware store or lumber yard. It can be ordered with automatic transmission, captain's chairs, and 2-door or 4-door body styles. All for thousands of dollars less than other comparable vehicles.

This Isuzu handles like a station wagon. Works like a Trooper. No wonder it became the fifth member of our family.

Making Decisions About Remodeling Your Own Home

If you own an older home, you'll inevitably need to decide whether or not it's in good enough condition to live in over the coming years. If you decide that it isn't, then you can either sell it for whatever you can get for it or you can make the necessary renovations, changes and improvements that will enable you to continue happily living in it. It's likely that remodeling will also tend to increase its eventual resale value.

Look at your home honestly and critically. You may want to ask for an opinion

from an appraiser, real estate broker, structural engineer or other qualified outside advisor. Your older home may show the damages of years of settling, water damage, termites, ill-advised "improvements," and simple, normal wear and tear. Over time, it may have become a hodgepodge of styles, finishes and designs rather than reflecting its original intent and construction. In addition, your neighborhood may have gone through a transition, desirable or undesirable.

If you decide to stay put and improve your present home, restoration to its exact original state is a possibility, but this isn't usually your best choice, unless your home is a historic showplace. Renewal, renovation or remodeling are terms that you may encounter for other options, usually involving improvements. For example, you might combine the technological advancements in heating, cooling, energy, insulation, finishes, and various interior and exterior materials with the best features of the existing structure.

Look at your neighborhood and at other remodeled homes. Study what contractors, designers, builders and others are doing in the area. Then use the best advice you can gather and make plans that are consistent with your budget and time requirements. Consider, examine, plan. Think of present value, probable costs and eventual potential value. This is the stage to make changes. Later on, changes can become very expensive, so think ahead. Be realistic about how much you can do yourself and how much you'll need to have done for you.

Your own benefits may be the pride of accomplishment; staying in your own familiar neighborhood; keeping your children in familiar surroundings and schools; enjoying lawns and trees that are long established; avoiding the expenses of moving and renegotiating your mortgage at a higher interest rate; or many other reasons. Not the least of these is the simple joy of turning the home you love into your family's dream home. If you've been happy there, and the home is basically sound, why move? Why uproot

the family if you can remake your older home into a showplace? Especially, why spend money unnecessarily on a newer home if the old one, when fixed up, will be a better dollars-and-cents investment?

Moving to Another Area

As mentioned earlier, a business transfer, retirement or other practical reason may make a move to a new area necessary. It may also be desirable for the family to move to another area of the same town.

If you decide to enter the market for a "handyman's special," whether it's to fix it up yourself or to have a professional firm tackle the job, here are a few tips to help make it easier to choose the right house.

Buy the newspaper from the potential location or have one sent to you and study the real estate section. In all probability, you'll want to use a reputable Realtor® to assist you in your search, and from the newspaper you can get an idea of which ones are most active in the new area. You'll also get a concept of price. You may already have a contact with a national franchising firm that is listing your present home. Ask them to help.

Nothing, however, replaces a personal visit to the area and driving through various target neighborhoods. If you are on your own on the first visit, jot down names and phone numbers of Realtors® whose signs are displayed in front of homes that seem to fit your criteria. Sooner or later, you'll probably want to select one firm and one person to guide you. Take your time. Be critical.

Above all, you should be comfortable with your Realtor®. Make sure that he or she understands exactly what you want and what you can afford. If you have no confidence in one Realtor®, or if the Realtor® can't seem to understand you or help you, find another.



One Isuzu extra that we quickly appreciated was a pre-cut hole in its rear bumper system, especially designed to add a ball joint, making it a quick-change hauling partner.

How to Select and Work With a Realtor®

If you're relocating, you'll find that a Realtor® or broker or agent can be of enormous help in the complex business of finding and buying a home, and perhaps later on in selling it.

The term Realtor® is a registered collective membership mark which identifies a member of the NATIONAL ASSOCIATION OF REALTORS® (whose information we are using). Members subscribe to its strict Code of Ethics, and membership generally signifies that the Realtor® has taken educational programs and seminars, as well as qualification tests.

Most real estate firms also belong to the local Multiple Listing Service, sharing each other's listings, and are thus better equipped to know about all homes available. In the MLS book, homes are arranged by price in each town or area, with photos and pertinent information. Visit any home that might appeal to you but check the Realtor's® computer print-out first because MLS listings aren't always reliable.

A Realtor® can serve only one client, usually the seller. Acting as a liaison between the parties of buyer and seller, he (or often she) must deal fairly with all. He must know the area and keep abreast of changing conditions, values, taxes, services, facilities, schools, etc. He can help you determine how much you can actually afford and suggest improvements that will be good investments in future resale value.

A Realtor® can advise you about other professionals, such as an attorney, and make recommendations. He or she can tell you what financial data you'll need, often help you get the best financing available in the market, and also assist you through the closing process and the documents and agreements involved.

Before you buy, there are many things you should do. Always drive around the neighborhoods and ask questions. Observe traffic patterns at different times of the day. Find out the resale value of neighboring homes so that the value of your home, after improvements, will fit in. Determine the actual selling prices that comparable homes brought. Find out about neighbors and schools. Examine the lot for privacy, size, contour, landscaping potential and possible drainage problems. Check for encroachments or easements. If you make an offer, make the contract contingent upon a satisfactory plot survey and structural inspection.



Get Ready for a Hard Day's Work by Wearing Comfortable Clothes and Boots.

One of the little tips that makes remodeling tasks easier is to dress correctly for the working day. Wear comfortable, well-fitting clothes and boots that are right for the job and the temperature.

If you're doing exterior demolition, it makes sense to wear different clothes and footwear than if you're putting the finishing touches on a heated kitchen. Make sure that you're warm enough, but don't get overheated. Take an occasional break to cool off.

We found that pants, jeans, shirts and gloves by Dickies™ gave us the right combination of rugged durability and go-anywhere looks. You can wear good-looking pants by Dickies at the real estate office, to the building materials store or

on a job site. Hardworking clothes by Dickies can take whatever you dish out, even when you're doing the toughest, most demanding job. Many people who know the famous Dickies pants are not aware that Dickies also makes long-lasting Brander's™ jeans, as well as stylish shirts and a wide range of work gloves.

Georgia Boot® has been designing and manufacturing boots and shoes of proven high quality since 1942. Their work boots, constructed of the finest materials, are not only comfortable but also come in a variety of handsome styles. Their long-lasting leather boots can be worn almost anywhere. A cautionary note: To insure proper fit, wear the same kind of socks when you're shopping that you'll be using when you wear the boots. Then walk around in the boots a bit at the store while you're trying them on to see that they fit you properly. Comfortable safety footwear is also available from Georgia Boot.

Look at the Potential for Interior Redecorating.

In the photograph below, the Realtor® answers questions concerning possible interior decoration. For the renovation of rooms such as this, we will be preserving the beautiful dining room mantel, as well as using such quality products as Wilsonart® brand decorative laminates, Marvin Windows and Glidden Spred Satin® Latex Interior Paint. The family's wardrobe is by Dickies. In the backyard photograph above, the father is wearing long-lasting Brander's jeans, handsome shirt and rugged work gloves by Dickies, while the son is wearing Dickies jeans and jacket with Georgia Boots.



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Great Workwear ...That's The Plane Truth!

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shirts, thermal underwear, socks,
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A Good Location: Madison, Georgia



The splendid Classical courthouse dominates the Madison town square.



Residents of the region enjoy the Madison-Morgan Cultural Center.



This home is typical of the beautiful renovations in the neighborhood.

Madison, in northern Georgia some 50 miles from Atlanta, has been described as one of those rare places where progress and advancements take place without destroying the history, refinement and character of days gone by.

Residents are committed to preserving the quality of life of the town. A large portion of Madison is listed on the National Register of Historic Places. There is an active Morgan County Historical Society, along with an equally active Chamber of Commerce.

In this remodeling case history, renovations and improvements will be made for improved modern family living. It is extremely important to a family in such a situation that there are other renovated homes nearby, evidence that fix-up expenses can be justified in terms of increased resale value.

It is also important to our family that Madison is within easy commuting dis-

tance of Atlanta. Madison is often called "The most picturesque town in Georgia," with handsome pre-Civil War homes and spreading shade trees that flank the streets of the town, which was once part of the stage coach route from Charleston to New Orleans. In addition to many splendid homes and fine churches, we found a historic Classical courthouse and the Madison-Morgan Cultural Center where art shows, ballets, operas, lectures and stage plays are presented in a restored schoolhouse which dates back to 1895.

Morgan County was named for the Revolutionary War hero, General Daniel Morgan. Madison, incorporated in 1809, is the county seat. During the Civil War, Madison was spared the fire and destruction which were the common fate of other towns in Sherman's path when former Senator Joshua Hill met the Union Army with a personal plea that the town be spared. Along with many

other beautifully renovated historic residences, Senator Joshua Hill's home still "stands proud" in Madison.

Family life is pleasant in the area, which has a variety of enjoyable recreational activities. There is an impressive lake, with wildlife habitats, boating, parks and other public recreational areas. Near Madison is a challenging 18-hole public golf course, as well as tough private clubs. There are tennis courts, parks and swimming pools, and the children's sports programs are outstanding. Residents say the hunting and fishing are also exceptional.

There are three public and two private schools, a regional library with 120,000 volumes, plus medical and dental facilities—all important considerations for our family.

All in all, Madison more than satisfies our most important requirement for a relocating family: GOOD LOCATION.

Planning and Looking

1. **Be realistic!** If you're buying, what can you afford for an immediate down payment and the monthly mortgage?
2. **How much is left for fix-up expenses?** Again, be tough on yourself and set a realistic figure. If you are going to bring in professionals, get a good cost estimate. Are you going to do much of it yourself? Over what period of time? Will you have enough left over for materials, tools and specialized subcontractors such as electricians, plumbers and structural firms?
3. **Pick a location.** Does your financial situation permit you to go into your chosen location? Study the area carefully. Most advisors say that *location* is far and away the most important

factor in buying a home or in deciding to stay in your present home.

4. **Ask questions.** Find out all you can: taxes, schools, population trends, dollar value of neighboring homes, possible rezoning for industries, jobs, recreational and cultural facilities, and recent sales of homes in the area.
5. **Tell your Realtor® the truth.** Find one you trust and who is frank and candid with you. Then confide your housing goals, likes and dislikes and pertinent information about your financial situation.
6. **Use your Realtor® to full advantage.** Ask for information about down payments, available mortgage money and interest rates. Find out whether the Realtor® can pave the way with a

local financial institution, introduce you to local people with interests similar to yours, or do other valuable favors. You'll be surprised at how much help Realtors® may be to you.

7. **Don't waste time with "maybes."** You can quickly learn which houses are worth an inside tour. Avoid the others. If you're using a Realtor®, he or she will appreciate this and will also be able to select candidate homes faster and more accurately.
8. **Be cautious!** Even if you fall in love at first sight, before making an offer you should still take time to think it over—at least until the next day. Remember that buying a house is the single largest expenditure most families ever make.

Structural Inspection

(After Your Preliminary Selection of the House)

Let's assume that you have now found a house you think is perfect. Don't go overboard before it's inspected for structural soundness and before you have it appraised.

Most home buyers should follow up their own careful inspection by having a professional evaluate the structural and mechanical components of the property *before* deciding to buy it. You usually need a professional's report for the financial institution when you apply for a mortgage, and it's a good investment in any case.

If the report contains negatives, you can then decide whether it's worth the time and expense to correct them or whether to go elsewhere. Ask the sellers, perhaps through their Realtor®, if they will permit this structural inspection by a professional *prior* to your offer. Otherwise, be sure to make a satisfactory inspection report a vital condition of any offer to buy.

Our inspector for the Madison house, Dick Jolley of Atlanta, used a detailed inspection form on which he rated virtually every part of the house as performing its intended function; performing part but not all of its function; not performing or unsafe.

The house selected for this series was graded as structurally sound overall, but with a few cautionary warnings concerning the porch, rain-carrying equipment, chimney masonry, circuit breaker, insulation and soffit ventilation. After all, you can't expect a totally clean inspection report on an 80-year-old house. But we were assured that there was no major water or rot evidence and no active termite infestation.

You should at least consider a similar inspection of your own home before making major remodeling investments in it.

All things considered, this house was rated as satisfactory for remodeling.

The completed inspection report can and should evaluate any of the following that are applicable to the house.

Exterior walls	Plumbing stacks
Siding	Girders
Windows	Joists
Storms	Columns
Screens	Walls
Doors	Basement floors
Trim	First floors
Outbuildings	Water penetration
Electrical service	Rot evidence
Grading	Water supply
Drainage	Sewage disposal
Landscaping	Hot water heater

Decks
Porches
Retaining walls
Fences
Driveways
Walks
Patios
Roofs
Roofing
Gutters
Downspouts
Flashing

Appliance hookups
Heating
Cooling
Insulation
Ventilation
Storage
Kitchen counters
Kitchen appliances
Fireplaces
Bedrooms
Bathrooms
Chimneys

Very importantly, the inspection report should tell you if there is any evidence of past termite damage, which you probably can live with, or active termite infestation, which should cause you to rethink before you proceed with the house. There is a growing concern about the presence of radon gas in a structure, so a radon test is also a good idea.

Tip: The average radon level can change as much as 60% from season to season, and can change with barometric pressure, so continuous monitoring of day-to-day changes is a good idea. The Survivor 2, from Threshold Technical Products, provides both short- and long-term protection for any home. It is simple to operate and satisfaction is guaranteed.

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New Raingo™ Gutters and Downspouts Will Replace Unsightly Equipment.

The deteriorating rain-carrying system on our older home, shown below, will be replaced by a new patented Genova Raingo™ system with a one-two punch. During rainfall, the unique design of the Highflo™ Drop Outlet draws water and debris towards the downspout area, while the Leafgo™ Debris Separator screen pushes out debris. No more clogged downspouts. Easy, do-it-yourself installation. Solid vinyl stands up to year-round weather and adapts to metal gutter. In a later issue, you'll see the attractive new Genova Raingo gutters and downspouts as installed.





The appearance of the older home will be improved considerably by new Marvin Windows, which will be specially made to order to fit the existing openings.

Marvin Windows™ Are Made to Fit, Because They're Made to Order.

Marvin makes windows to order in more than 8,000 standard sizes and shapes and has unlimited custom capabilities. When architect Zoe Van der Cleveland specified Marvin insulating glass windows, Marvin informed us that they would record our window requirements, including size and other important information, so that the windows would fit our home perfectly.

The best thing about Marvin, according to our Atlanta architect, is not just that they make so many varieties of windows, but how well they make them. He said that he chose their double-glazed windows to improve the interior comfort and reduce energy costs. In addition, he chose their fine-grained Ponderosa pine sash, casing and jambs because of their insulating qualities and the way the wood accepts a paint finish. And he had the choice of an aluminum-clad exterior, which gives the warmth of wood inside and maintenance-free, extruded aluminum outside, or of a tough, factory

Increased Energy Efficiency— An Investment That Pays Off

Increasing the energy efficiency of the home you own or are buying could be one of the best remodeling investments you can make, and this was a major consideration in remodeling the Madison home. In this energy-efficient home, we'll use weather-stripping, good exterior caulking from Red Devil™, Marvin™ insulating windows, insulating doors, a high-efficiency Reliance™ water heater, and a high-efficiency Lennox Pulse™ gas furnace and two-speed air conditioner.

Good Insulation. Owens-Corning Fiberglas® Corporation, a leading manufacturer of energy-efficient building materials, supplied the insulation for our *Popular Science* remodeled home, plus

cured finish which resists cracking, blistering or peeling under even the most adverse conditions.

Every Marvin window carries the stamp of craftsmanship. The windows are made in Minnesota, where temperatures can plunge to 40° or 50° below zero, but energy-efficient windows are just as important in insulating air-conditioned homes against Georgia's summer heat. Marvin windows are deep-treated with a PILT solution to protect against rot and decay. They're beautiful to look through and look at—and they stay that way longer with less care.

WHEN IT COMES TO REPLACEMENT WINDOWS, CLOSE DOESN'T COUNT.



You need a window that doesn't fit like you need a hole in the wall. But if you have a non-standard opening, that's exactly what you get with most replacement windows. Instead of messing with fit kits and extenders, why not specify the brand of window that's made to order, so it fits exactly right, right from the start. Every Marvin window is carefully constructed by hand to your specifications, regardless of shape, size or style. Standard or custom. For more information about Marvin replacement windows, return the coupon below or call toll-free **1-800-346-5128** (In MN, 1-800-552-1167, In Canada, 1-800-263-6161).

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HOW TO UPGRADE
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INSULATION CONSIDERATIONS
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Owens-Corning just wrote the book
on home insulation.

This comprehensive 32-page guide
features the latest government insula-
tion recommendations plus many other
tips to help you save on your energy
bills. So if you're planning to build a
new home, add on to your house or just
reinsulate, get a little free advice from

the insulation experts. Owens-Corning
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OWENS-CORNING
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Mail to: Owens-Corning Fiberglas Corp., Attn: C.F.M. Meeks,
Fiberglas Tower, Toledo, Ohio 43659.

Please send me a free copy of "A Homeowner's Guide to
Insulation."

Name _____

Address _____

City _____

State _____ Zip _____



Think About Future Expansion Room Early.

When you're looking, consider possible expansion when you check basements or attics which may be finished later into children's bedrooms or play areas or home offices. Owens-Corning Fiberglas® batt insulation will make winterizing the attic an easy do-it-yourself project. Shoes by Georgia Boot, pants by Dickies, camera by Olympus.

their Oakridge® architectural roofing shingles, and passed along valuable advice for homeowners. This included the upgraded recommendations issued recently by the U.S. Department of Energy (DOE). These new recommendations are further confirmation that the right amount of insulation can help save on heating and cooling costs and make your home more comfortable.

Dr. Dave McElroy, of Oak Ridge National Laboratory, which helped develop these recommendations, said that the new recommendations take into account the increased cost of heating and cooling the home over the past several years, and that insulation is relatively inexpensive, with a favorable cost/benefit ratio that makes increased insulation levels worthwhile.

Regional R-Value Upgrades. Specifically, the DOE increased its minimum R-value recommendations for the country's various climates. An R-value is a measure of insulation's resistance to heat flow. Tiny air pockets trapped in insulating material resist the passage of heat gain in warm summer months and heat loss in colder fall and winter months. The higher the R-value, the greater the insulating power.

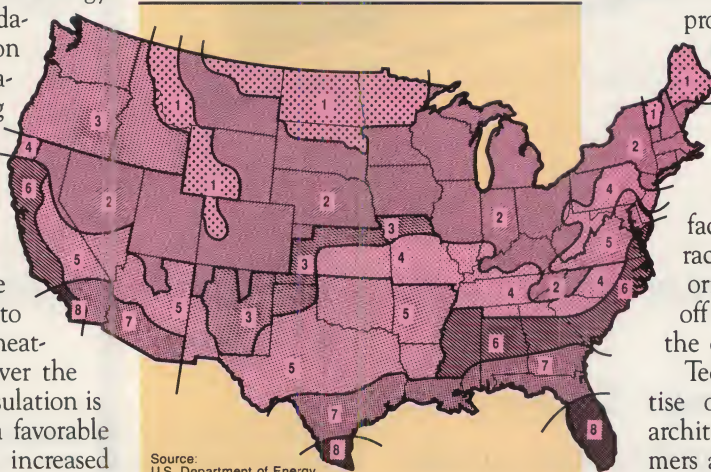
The information collected for the new R-value recommendations was specific to zip code areas and takes into account climate, heating and cooling needs, the forms of heating used and prices of energy. For your location, see the map below.

The conclusion: no matter where you live, insulation is a good investment.

All Around the House. The new recommendations also cover several other important areas of the home: ceilings, floors, exterior walls and crawl spaces. Although insulating an unfinished or unfloored attic is probably the most popular do-it-yourself insulation project, homeowners need to be aware of places all around the house where significant amounts of energy can be saved.

The chairman of the Alliance to Save Energy, Senator Timothy E. Wirth of Colorado, said that recent Alliance field tests show that in homes where major weatherization retrofits were applied, wall insulation and new high-efficiency furnaces were the most effective energy savers. Average heating and cooling costs were reduced 24 and 32 percent by these two measures, respectively.

\$100 Billion Bill. "It's important that homeowners take the new guidelines seriously because Americans spend \$100 billion on household energy annually. That's over \$1,100 per household. Energy is the largest cost of home occupancy, after rent or mortgage payments," Senator Wirth stated.



Source:
U.S. Department of Energy

Recommended Insulation R-Values for Your Area

Climate Zone	Electric Resistance	Gas or Oil	Crawl-spaces	B Exterior Walls (Wood Frame)	C Crawl Space Walls
1	49	49	19	11	19
2	49	38	19	11	19
3	38	38	19	11	19
4	38	38	19	11	19
5	38	30	19	11	19
6	38	30	19	11	19
7	30	30	(D)	11	19
8	30	19	(D)	11	11

- A. Assuming no structural modifications needed to accommodate added insulation.
 B. R-Value of full 3½" thick wall insulation will depend on material used. Range R-11 to R-13, with R-19 recommended for new construction.
 C. Insulate only if crawl space is dry all year, all ventilation is blocked and floor above not insulated. Use vapor barrier on ground to reduce moisture migration.
 D. Additional insulation for cooling is not recommended.

The DOE estimates that 50 to 70 percent of the energy used in the average American home is for heating and cooling, yet most existing houses are not insulated to recommended levels.

An attic insulation study conducted by National Family Opinion, an independent research firm, found that the average insulation level in attics today is around R-20. The DOE now recommends an average level of R-40.

The bottom line is that insulation works from the moment it is installed. With the new recommendations, people can make their home more valuable while decreasing the bills they are paying. Insulation can improve comfort and reduce both heating and cooling costs year-round.

To receive more information about the new DOE recommendations, send for a free copy of *The Homeowner's Guide to Insulation and Energy Savings* by writing to M.S.U. Meeks, Owens-Corning Fiberglas® Corporation, Fiberglas Tower, Toledo, OH 43659.

Remodeling Contractors and Customers Benefit from New Space Age Technology

When you're choosing a contractor, it makes sense to look for one who has access to the latest in technology, such as the Techsonix™ Digitizer System. This state-of-the-art estimating system has propelled construction estimates into the next century, so that contractors' estimates or bids are very, very close to the actual costs. The experiences of industry users indicate an extremely high degree of satisfaction with the system's accuracy and speed. Techsonix is the originator of computer-aided take off and estimating systems for the construction industry.

Techsonix combines the expertise of builders, contractors and architects, plus computer programmers and technicians, into a quick and accurate method of preparing cost estimates, take offs and preparing quantity surveys.

If this sounds complicated, it's because the system is so far advanced. It enables the professional contractor to use a stylus on a set of plans—perhaps the designer's plans for your remodeled home—and measure lengths, widths, heights, volume, angles, weights, and depths to estimate quantities and costs. Based on these calculations, he can quickly prepare an



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Just climb onto a Kubota and enjoy your view from the top-of-the-line compact tractor.

With the new B-Series, we've reached what we think of as a turning point in tractor design. It's called the Bi-Speed Turn.

Most simply, the front wheels take corners sixty percent faster than the rear wheels. Sharp turns are not only tighter than those of

ordinary 4-wheel drive, they're smoother, less damaging to turf, far less unsettling to the driver.

But then, Kubota has been the innovation leader since we introduced the first compact tractors to feature liquid-cooled diesel engines, 4-wheel drive and hydrostatic transmissions.

Service and support are ever present because, unlike many

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estimate for your project that gives you a sound basis for making your own plans and decisions.

Techsonix programs are written in the language of the construction industry. More than 3,000 general contractors, subcontractors, building materials sup-

pliers, estimators and others are using Techsonix systems throughout the world. The newest of these is the powerful Master 2000C® program, an advanced program which performs every take off and estimating operation known to the construction industry.

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TECHSONIX
Now Introduces
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Every day—somewhere in the world, millions of dollars of accurate construction estimates are being completed by Techsonix customers. **Are they your competitors?** ...

And now, they can do it even faster and more accurately than ever before with the Amazing MASTER 2000C program.

The Ultimate computerized **DESIGN, Takeoff & Estimating** program ... **DESIGN IT ... QUANTIZE IT ... PRICE IT ... All AT ONE TIME.** The program interfaces with Auto/CAD* which enables the user to draw the plans in color as before, but now provides quantities and costs concurrently.

Techsonix is pleased to have been selected by Popular Science for participation in the "Win This Home" Sweepstakes construction project.

Want to learn more? ... contact the Marketing Dept.:



The Techsonix Building
9675 Businesspark Ave. • San Diego, CA 92131
(619) 549-9563 1-800-888-1983 FAX 619-549-8721

What Radon Is And What You Can Do About It.

The United States E.P.A. and Centers for Disease Control are currently quite concerned about the risk of lung cancer among people exposed to excessive radon gas in American homes. According to scientists' estimates, about 5,000 to about 20,000 Americans will die of lung cancer brought upon by exposure to radon. Your risk of developing lung cancer depends upon the concentration of radon gas and the length of time over which you are exposed, and this risk increases as both the level of radon and the length of exposure increase.

So if radon is such a potential hazard, what is it? And what can you do to avoid its dangers?

Radon is a radioactive gas which comes from the natural breakdown (radioactive

decay) of uranium. You cannot see it, smell it, or taste it. It varies as much as 60 percent from season to season. While radon is so diluted outdoors that it causes no problems, it can accumulate inside your home, depending on the building's construction and on the concentration of radon in the soil underneath. It can vary from your home to your next-door-neighbor's home. Changes in the barometric pressures can cause important elevation in radon concentration.

Radon has always been present in the atmosphere, but it wasn't until a generation ago that high indoor radon levels were discovered in some American homes.

Later, cases of high indoor radon concentrations were found in various parts of our country, generally caused by natural deposits of uranium in the soil on which houses are built. No one knows which

homes have elevated radon levels and which do not, without testing.

Radon moves through small spaces in the soil or rocks upon which a house is built and can enter the home through cracks, drains, sumps, joints, dirt floors, block walls or even private wells. In general, building materials are not a major source, although there are exceptions.

Since you cannot see or smell radon, special detection equipment and procedures are needed to protect your home from the dangers of radon gas. One involves a short-term screening measurement (not a reliable measure of average radon level), followed by a determination of the need for further measurements.

Fortunately, you can have both short-term and long-term protection through Survivor 2, a product of Threshold Technical Products, a Charter Member of the American Radon Association. Satisfaction is guaranteed. The Survivor 2 is simple to operate and gives continuous monitoring of your home's environment for the past 12 hours or the past year. It has microprocessor control which changes from a normal "all's well" green light to a red light when the radon concentration level equals EPA recommendations or exceeds them.

A few other tips from government publications: Smoking may increase the risk of exposure to radon. If you spend more than 75 percent of your time at home, take that into account. Persons who sleep in the basement are more at risk than those in second-floor bedrooms. Whenever practical, open windows and turn on fans, especially in the basement. Keep any crawl space vents open. Children may be more at risk than adults. Consider the total time you expect to live in your home, but also consider that other houses may have the same—or even higher—levels of radon.

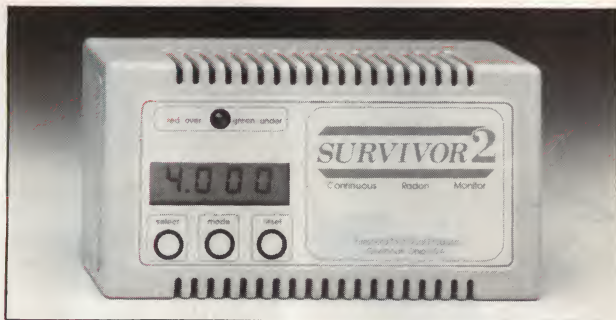
Once again, the price for peace of mind seems a small one to pay.



Pay close attention to less glamorous areas, and check insulation, ventilation, and utilities. Watch for any evidence of water or seepage problems below grade. The handsome shoes are by Georgia Boot®.

Radon Monitoring

Survivor 2...short and long term protection for your home.



RADON is the radioactive decay product from uranium and radium.

- According to EPA estimates, radon causes between 5,000 and 20,000 lung-cancer deaths a year.
- Of the more than 15,000 homes tested by the EPA in the last two years, about one fifth had levels above 4 picocuries per liter.
- The EPA estimates unsafe levels of radon gas are in as many as 8 million homes in the United States.

With statistics like these, don't you want to protect your home from the dangers of radon gas?

Radon is odorless and colorless. It varies from season to season. It varies from neighborhood to neighborhood. It can even vary from your home to the home next door.

Why Continuous Monitoring?

It is estimated that the average radon level changes as much as

60% from season to season, while a simple change in the barometric pressure can change the level of concentration to at least five times the average level.

Now you can have CONTINUOUS monitoring of your environment for day to day changes in radon levels. SURVIVOR 2 will give you a continuous instant LCD readout of the level of radon in the last 12 hour period, or the last 365 days. Long term monitoring of your environment with SURVIVOR 2 will give you the average level of radon. The typical charcoal canister will only give the highs and lows from a one or two week period.

Simple to Operate

SURVIVOR 2, with its microprocessor controlled features, is simple to operate. In the 12 hour mode, a bi-color LED gives you a green light if the average radon level is below four picocuries per liter (which is the level recommended

© 1989 Threshold Technical Products

by the EPA), or it automatically changes to red when the level is equal to or exceeds that EPA recommended level of four picocuries. By using the MODE switch, SURVIVOR 2 will display the average level of radon in the last 12 hours, or it will display the average level for the last year.

Satisfaction Guaranteed

Try some peace of mind at no risk. If you are not completely satisfied, return it within 30 days for a complete refund. Of course, SURVIVOR 2 is backed by a one year limited warranty on both parts and labor.

How to Order

By Phone: Call us toll free. A member of our sales staff will be glad to answer any questions and take your order. (Please have your VISA OR MASTERCARD available when you call.)

Call Toll Free 800-458-4931

By Mail: Send your name and complete address, daytime phone number, and how many SURVIVOR 2s you wish to order. Please enclose a check, money order, or card number and expiration date from your VISA or MASTERCARD.

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When to Use and How to Choose an Architect

If you're considering the total remodeling of an older home, someone is going to have to draw up the plans for such work. If you can't do it, do you want the contractor to do it? If not, it makes sense to employ a well-qualified professional.

Even though you may flinch at the thought of paying an architect or architectural designer to help you remodel your home, it could be a good investment. He should be able to help in improving the appearance of the renovated structure and also in getting maximum comfort, livability and potential resale value.

Using an architect to tailor a home just for one particular family does carry a substantial price tag, but there are ways to reduce the fee. For example, if you develop a plan yourself, you can pay him to review it. Or you can employ him to guide you in your early planning. Get an idea in advance of his fee for such basic services.

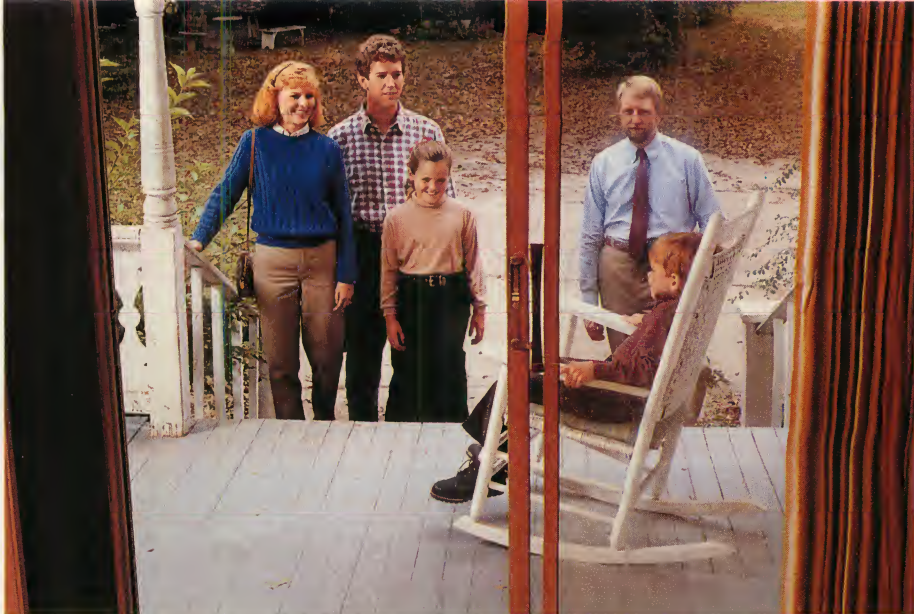
You'll have to pay more for complete material specifications and much more if you want day-to-day supervision. Architects charge a percentage of costs, so he can work with you on that basis only if substantial expenditures are involved. Otherwise, agree on a fee.

Look for an architect who is experienced in residential remodeling and enjoys it. Not all architects qualify. Ask for references, then follow up on them. Ask local builders or contractors for suggestions, positive or negative. Above all, find one you're comfortable with, can talk to, and have confidence in.

But you must do your share. Think through your family situation, budget and requirements and be as precise as possible in your discussions. Don't be ambiguous. Ask for a preliminary plan and options. Go over them with him and tell him what you think, but allow some freedom. After all, you're paying for his creativity and knowledge. Remember that the earlier changes are made in a plan, the less expensive they are. Think things through carefully so as to reduce job-site changes which wreck budgets, quotes and schedules.

If you have the original blueprints of the house, turn them over to him. Ask for advice on materials, products and contractors. Have him help with local codes, ordinances, permits, zoning, etc.

Working with an architect can be a rewarding experience, if you choose an architect with residential remodeling experience and use him wisely.



Clean Up Yard Debris With Less Work—and Get Useful Mulch.

In the backyard of our Madison property, we faced the problem of debris—brushes, branches, hedge trimmings, limbs, leaves and other clutter. These spoiled the looks of the home, and there was no place to hide them.

Sound familiar? Probably. The fact is that many yard and garden projects create debris that's a real problem to dispose of: You can't throw branches and rough brush into a compost pile and you can't spread them for mulch. The stuff is worse than

useless because there's no good way to get rid of it. Or is there?

Troy-Bilt Manufacturing has found a way to recycle it. Manufacturers of the famous Troy-Bilt® Rototiller, they also produce a line of chipper/shredders under the Troy-Bilt "Tomahawk" name. With this equipment, you can stop piling, burning and hauling away yard debris, because it's very simple to turn such wastes into free wood chips, mulch and compost.

Originally we had considered one of the larger model Troy-Bilt Super Tomahawk® chipper/shredders. But when Troy-Bilt reviewed our plans, they told us that their all-new, small-property "Junior Tomahawk" would be better suited for the size of our property. They were right. The Junior Tomahawk is a perfect choice for any suburban or small-property homeowner. It made short work of shredding jobs that would have bogged down an electric shredder, and it easily chipped branches up to two inches in diameter. The oversized hopper took leaves, rakings and yard debris by the armful. Best of all, we used the shredded organic matter produced by the Junior Tomahawk to smother weeds and provide slow-release fertilizer for vegetable and flower beds.

The Junior Tomahawk lived up to all of our expectations, made cleanup easy, and enabled us to turn yard debris into useful mulch and compost material. When you look at your property, or at a new home, keep in mind that now there's a way to get free mulch in addition to cleaning up the yard or garden.



NEW... Low Cost, Home Property

"Clean-up Machine"

The New Junior TOMAHAWK® Chipper/Shredder rids your property of unsightly yard debris... and turns it into FREE mulch and compost material!

The Junior is unlike anything previously available to suburban and small property owners.

It's as easy to use as a kitchen garbage disposal...costs less than a good quality mower...and takes up less space in your garage than a trash barrel.

Yet this compact dynamo solves one of the thorniest problems homeowners face in trying to keep their places looking nice ...what to do with all the leaves, brush, branches, prunings and other yard debris that accumulates so quickly.



At last!...there's a FAST, EASY way to clean unsightly brush piles and other yard debris from around your property!

Ideal for small or suburban properties!

The Junior is lightweight and completely portable...compact for easy storage...much quieter than larger machines...so trouble free it carries a Full No Time Limit Warranty...and best of all, so affordable that now suburban and small property homeowners can easily justify the convenience of owning a full performance shredder.

Recycles ALL your yard wastes!

Unsightly and hard to manage prunings, branches, weeds, suckers and garden leftovers can now be cleaned up on the spot and put to good use!

For complete information on this remarkable new small property "Clean-up Machine," please mail the coupon TODAY.



Big, oversized hopper takes leaves, twigs and other loose materials by the armload!

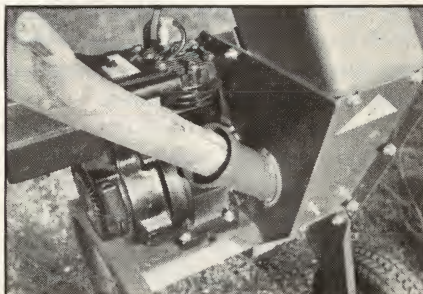
No more bagging, dumping or accumulating yard debris!

With half the nation's landfills scheduled to close within five years, tossing out our yard debris with the trash could soon become a thing of the past.

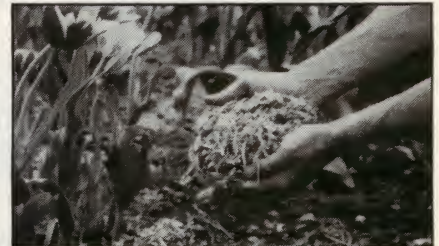
But now, with the Junior TOMAHAWK® Chipper/Shredder, you can easily reduce these yard wastes in bulk and put them to productive use.

The Junior TOMAHAWK beautifies your property this easily:

- **Eliminates ugly brush piles**—cleans up fallen branches, winter damage and yard debris after storms.
- **Puts Fall leaves to good use**—shreds Fall leaves into a fine, compost-like plant food for feeding your prize roses, your garden and your lawn!
- **Makes landscape chips**—turns branches up to 2" thick into attractive wood chips for smothering weeds around trees and shrubs.

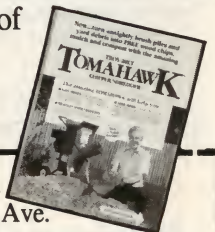


The Junior TOMAHAWK's direct drive and weighted flywheel enable it to chip 2" thick branches with ease.



Makes attractive wood chips for landscaping and keeping down the weeds!

Send for your **FREE CATALOG** on the full line of small and large TOMAHAWK models!



Troy-Bilt Mfg. Co.
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Troy, NY 12180

Dept. A1029

☐ **YES!** Please send me your FREE Catalog on how the 3 HP Junior TOMAHAWK® Chipper/Shredder can help me clean up and beautify my property...plus details on factory direct prices, larger models available and your 30 Day Home Trial Offer.

Name _____

Address _____

City _____

State _____ Zip _____



ARROW®

(ARROW UNDERSTANDS) A MAN'S HOME IS HIS CASTLE

From the dungeon to the tower (basement to the attic), Arrow products are versatile enough to handle most any job — big or small.

With a full line of fastening products, Arrow has long been a source for Quality fastening tools for the professional and home do-it-yourselfer. Plus Arrow products have the reliability you have come to expect, at a price that's

competitive even if you don't have a castle.



See the complete assortment of Arrow Fastening tools, staples, glue stix, fasteners and rivets, available at all leading Hardware, Home Center, and Discount Department Stores.

Arrow Fastener Company, Inc.

271 Mayhill Street, Saddle Brook, N.J. 07662

In Canada: Jardel Distributors, Inc. 6505 Metropolitan Blvd., East Montreal H1P 1X9 Quebec

© Copyright 1988 Arrow Fastener Company, Inc.

Making an Offer to Buy

Never, ever make an offer to buy a house the first time you see it. Wait at least until the next day before you act.

Make any offer through the Realtor®, who is required to present all legitimate offers. The offer should be accompanied by "earnest money," usually a check for \$500 or \$1,000, made out not to the owner but to the Realtor®. On a direct deal, shake hands with the seller on the

offer but don't leave a deposit check, which could be difficult to recover if problems develop. Let the owner's attorney or yours hold the earnest money.

After the offer, it is too late to bargain and make trade-offs with the seller, so before you make the offer use your financial situation, available down payment and other factors to bargain for a lower price, for earlier occupancy, and to get items that you want left behind included in the price. Before you make the offer,

be sure that you have compared the actual—not *rumored*—selling price of comparable houses in the neighborhood with the price you are being asked to pay. Use local records and go in prepared.

There is no such thing as a standard real estate offer form. Make sure that your offer includes some "must" information, even if you must print it in yourself. The offer must have:

- Names and addresses of buyer and seller clearly identified as such.
- Legal address and description of property being sold.
- Amount of the offer and terms of the offer, such as the kind and amount of the mortgage you'll apply for and the highest rate you'll accept. Spell the rate out—don't settle for "prevailing rate" unless that's what you'll take.
- Any special provisions. Make sure the extras you expect to have included with the house are clearly listed and described.



You'll Grow Attached to Arrow® Fastening Tools and Fasteners.

Arrow's versatile fastening tools and fasteners will be employed for many uses in our remodeled home project. Either the Arrow model T-50 Staple Gun Tacker or the model HT-50A Hammer Tacker can be used to tack up the vapor barrier in the crawl space, as well as all of the insulation in the house, which will be an important contributor to energy savings. Both tackers are quality tools used by professionals and home do-it-yourselfers alike.

Arrow's complete assortment of fastening products includes its hot melt glue gun with non-drip nozzle, staple gun tackers, and staples, Xpando® fasteners and Xpando® anchors, glue stix and removable weatherstripping, rivet tools, rivets and other products that assure a good clean job. Arrow's exclusive features along with its quality make these Arrow products your best buy. Whether you want to staple it, tack it, fasten it, hammer it, rivet it or glue it, you'll grow attached to the quality line of Arrow fastening products.

In the photograph above, the workman is wearing rugged Dickies jeans and shirt with sturdy Georgia Boots.

As a precaution, include a statement that a commission of a certain percentage will be paid by the seller to the Realtor® or broker. If you're buying direct, make it clear that you do not expect to pay a Realtor® commission at some future time.

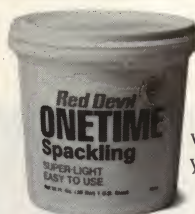
Put a time limit on the offer to keep the seller from making you wait for a decision. Before you sign, make absolutely certain that the agreement contains all clauses relative to structural inspections, pest inspection and title insurance. Include a clause that states that the offer is subject to having a contract drawn up (within a specified time) by an attorney. Otherwise, in some areas the offer may become a legal contract when signed by both parties.

You can then take a copy of the completed binder to your financial institution in order to begin the application procedures for a mortgage.

Think of the Potentials of Add-on Space.

Inspecting the kitchen, the prospective owner decided that she would replace everything, and add a great room. She plans to use Wilsonart® brand decorative laminate surfacing, which combines lasting beauty with ease of cleaning. Her certified kitchen designer can specify from the ColorVantage collection, a highly styled line with cabinets that coordinate perfectly with countertops. Glidden Spred® Enamel Latex Semi-Gloss will be used for repainting because of its excellent durability and scrubbability. Thinking ahead, she's already looking at energy-efficient Tappan gas ranges.

No Refills.



One time is all it takes to patch a hole with ONETIME® Spackling. It won't shrink, so you never apply a second coat. And you can prime and paint in minutes.

You've seen how fast it works on TV. Wait till you see it work on your wall. Look for ONETIME at your hardware or home center store.

Red Devil

New Tool Saves Hours of Backbreaking Work.

The Slamscraper™ Impact Tool, an innovative new tool from Red Devil®, makes quick work of

backbreaking cutting and scraping jobs. No more kneeling down with hammer and chisel. This workman found that with the Slamscraper® Impact Tool he was easily able to remove double-layered linoleum in the kitchen and heavily pasted linoleum in the bathroom. The tool's rugged construction withstands even the toughest daily demands. Caution: Safety glasses are recommended with the use of this product. The workman is wearing Georgia Boots® and Dickies™ overalls.



Shop for Mortgage Money

That's right—it's for sale like any other commodity, at various prices and under various conditions. So shop for what's best for you.

A mortgage is simply a device to convey property to a homeowner on condition that the transfer becomes void unless repayment terms are met. The property is security to the creditor that the loan will be repaid at a certain interest rate over a certain period of time. And all of this is negotiable. Your Realtor®, banker or lawyer can help you strike the most advantageous bargain.

Learn the important differences among a conventional, Federal Housing Administration and Veterans Administration loan. Remember that the FHA and VA do not actually lend out money or approve houses for loans. Federally sponsored mortgages are intended to make it easier and safer to buy a home. Normally, a conventional loan will be processed faster, but shop for rates, terms, conditions and requirements for the down payment just as you shopped for the house itself.

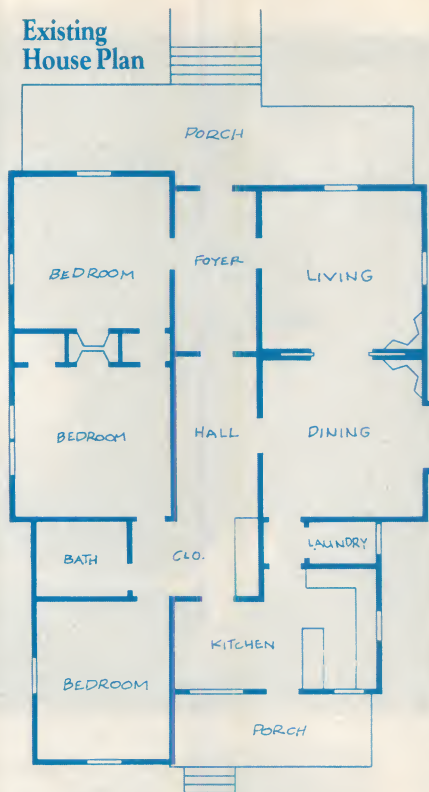
Don't forget to allow for the funds you'll need to remodel your proposed new home and be sure to leave plenty of money for unexpectedly higher moving and closing costs.

More People in a Home Mean More Bathrooms.

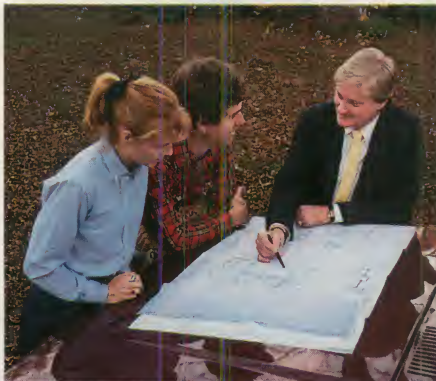
This single bathroom isn't really adequate for four family members, so in addition to updating it, a new bath plus a powder room will be added. Cabinets with Wilsonart® surfacing will complement pedestal sinks and add storage space. The expanded facilities will mean a heavier demand for hot water, so the old water heater will be replaced by a larger gas water heater by Reliance, which will be far more efficient, self-cleaning and will never need draining.



Existing House Plan



Floor plan subject to change due to product availability.

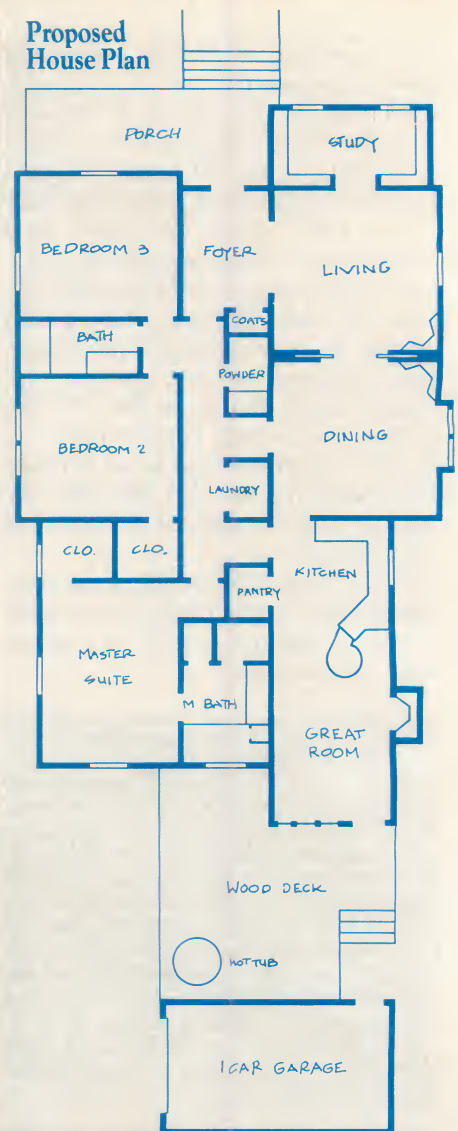


The Time to Make Changes: At the Planning Stage.

After the architectural designer, Zoe Van der Cleveland, had gotten to know as much as possible about the family's lifestyle and what they wanted in their new home, he met with them to show preliminary plans.

The family's expressed desire for a totally new, different living area at the back of the house is reflected in the proposed plan, which adds a generously sized family room, with new Valor® Homeflame™ gas fireplace, and a breezeway with Old South aluminum columns back to the new garage, which will have Temple-Inland's Ultra-Lap™ siding. Interior walls will be moved to make room for a master bedroom and bathroom suite, opening out on a new deck with a Hot Spring Spa® by Watkins. New laundry and closet space will provide room for a new washer, new gas dryer and a Reliance gas water heater. An additional bath and powder room, plus a renovated kitchen with a Tappan gas range, will feature Wilsonart® laminate surfaces on the cabinets. A book-lined study will be added to the living room. The whole house will feature gas, America's best energy value, with high-efficiency Lennox Pulse™ gas furnace and two-speed air conditioner.

Proposed House Plan



Energy-Efficient Gas Water Heater Reduces Heating Bills and Sediment.

If your water heater is more than a few years old, chances are that sediment buildup is forming a harmful barrier between the water and heat source, or burner. This drives operating costs up, reduces storage capacity, and causes premature tank failure.

Fortunately, there is a gas water heater that provides over 41 percent more hot water and saves over \$100 per year, based on the national average gas rate. The Reliance® Sta-Kleen® model 805, used in remodeling the *Popular Science* home, is totally self-cleaning and never needs draining. A patented Aqua-Force Ring® helps keep harmful sediment from collecting, increasing tank life and reducing operating costs. Extra-thick foam insulation and heat traps keep heat in the glass-lined tank. The multiport burner makes for quiet, efficient operation and the temperature control is conveniently located.

When you consider that a new water heater can be ruined in as little as five years by sediment buildup, it makes sense to invest in a self-cleaning unit. Add the energy-efficiency savings of gas and lower operating costs and it's easy to see why a gas water heater such as the Reliance Sta-Kleen® is a good remodeling investment that pays off in both comfort and energy savings.

Gas heats water for half the cost of electricity, according to the American Gas Association.



At the end of a long day, you'll be glad they're **Georgia Boots.**

Nothing can make a working or shopping day seem longer than cold, wet, uncomfortable shoes or boots. The tasks that you would normally enjoy become difficult chores when your footwear doesn't fit or hold up to the weather.

For more than 45 years, Georgia Boot® has been producing a full line of high-quality boots,

shoes and safety footwear, designed not only to look good anywhere but, more importantly, to fit just right and give long-lasting wear and comfort. We use only genuine leather and the finest nationally-known materials. Pick up a pair of our shoes or boots and make your day a bit more pleasant. Even if you spend it working.

Georgia Boot. The total line boot company.

P.O. Box 10, Franklin, Tennessee 37065-0010

Yamaha Terrapro owners find happiness right in their own backyard.



JOHN: "When we're done mowing the back, we just upshift and run right over to the front yard. Saves a lot of time."
WANDA: "By the way, I'm the one who does the mowing."

John & Wanda Purcell
Paducah, Kentucky



"The Terrapro's easy to maneuver and real smooth riding. And after mowing my acre and a half, I can take it down along the creek and have some fun."

Wayne Horstman
Ownesville, Missouri



"I can maneuver easily around individual fruit trees. Whereas anything larger needs a lot more room. And I can go all day without getting tired."

Mike Durbiano
Goleta, California

To paraphrase an old saying, "It takes a heap of mowing to make a house a home."

Also a heap of spraying. And hauling. And who knows what all.

To handle such tasks, insist the folks pictured here, you need the Yamaha Terrapro. The first ATV designed to do all of the above, when it's not busy taking you hunting, fishing or camping.

For example, you can attach a Yamaha finish-cut mower to the rear-mounted PTO (Power Take Off) hook-up for a magnificently manicured lawn.

You can use our rough-cut mower to whack away weeds and brush. Or a Yamaha sprayer to deliver fertilizers* and other liquid assets quickly and efficiently.

All the while sitting in solid comfort on a machine that's more maneuverable and easy to operate than any riding mower or tractor.



Tackle your gardening with the new optional 38" garden tiller.

After your Terrapro's done a good day's work, you're free to use its tough 348cc, 4-stroke engine and high-traction, high-flotation tires to take you where the fun is.

But first you need to find out where your dealer is. And to do that, you need to call 1-800-331-6060, ext. 675.

YAMAHA
We make the difference.™

ATV's with engine sizes of 90cc or greater are recommended for use only by those aged 16 and older. Yamaha recommends that all ATV riders take a training course. For safety and training information, see your dealer or call the ATV Safety Institute at 1-800-447-4700. ATV's can be hazardous to operate. For your safety: Always wear a helmet, eye protection, and protective clothing; never ride on paved surfaces or public roads; never carry passengers; never engage in stunt driving; riding and alcohol/drugs don't mix; avoid excessive speeds; and be particularly careful on difficult terrain.

Home Equity Loans

It's hard to beat a home equity loan, which permits you to use the equity in your home to borrow money to remodel it. Usually you can obtain a straight fixed-rate loan or a specified credit line in the amount of 75 to 80 percent of the assessed value of the home, including improvements, and minus any outstanding balance on your mortgage.

A home equity loan offers several important advantages. Usually, because the home is such good security, it is made at a lower interest rate and in a larger amount than you can get from your financial institution through another type of loan. And with a line of credit, you can draw the money at any time, for any reason. It's also normally easier to get a home equity loan application approved quickly and without giving as much confidential information. Plus, interest on a home equity loan is treated by the Internal Revenue Service as a deduction in the same fashion as your mortgage, even though Federal income tax laws are eliminating many tax deductions for personal loans, credit cards, etc.

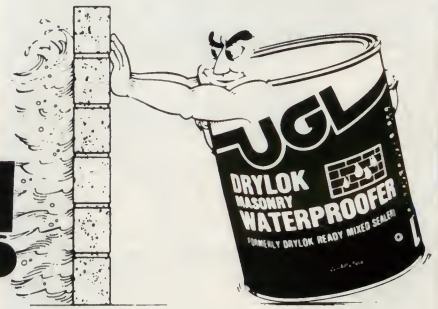
Once your remodeling project has been completed and your home is worth more, you can put that increased value to work as a line of credit for other purposes: future credit needs, tuition, investment opportunities, automotive loans, vacations and other credit needs, all with tax advantages that enable you to cash in on the increased value of your home without selling it.



Lots of Outdoor Work Ahead

There will be plenty of yard and garden uses for the Husqvarna® chain saw above, the Junior Tomahawk® Chipper/Shredder and Honda lawn mower. Also, the homeowner will find lots of work for the new Yamaha Terrapro™, the world's first all-terrain vehicle with power take off. The Terrapro four-wheeler, like other Yamaha Moto-4 ATVs and utility vehicles, features a powerful four-cycle engine, a dual-range transmission and large, high-traction balloon tires. Its PTO power allows the Terrapro to supply direct engine power to run the new Yamaha sprayers and mowers, as well as handle rugged countryside.

STOPS WATER!



DRYLOK MASONRY WATERPROOFER...

"The Paint That's Guaranteed* to Waterproof!"

Now you can turn that problem basement into a dry, comfortable den or workshop without worrying about water seepage! With DRYLOK Waterproofer, you can seal and decorate porous masonry walls above or below grade! DRYLOK is ready mixed...just open the can, stir and brush it on! And when applied as directed, DRYLOK* is guaranteed to stop water penetration for 5 years. You'll find DRYLOK Waterproofer at your nearby paint store, hardware store or family home center.

For free "How-to" literature on DRYLOK Waterproofer...write UGL, P.O. Box 70, Scranton, PA 18501.



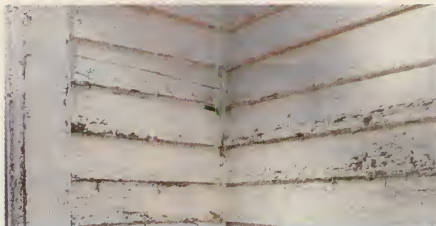
UNITED GILSONITE LABORATORIES • SCRANTON, PA • JACKSONVILLE, IL • VISALIA, CA

Waterproofing System Stops Seepage, Protects Above-Grade Masonry.

As you see in the photograph, the home rests on several courses of masonry that provide crawl space for utilities. The manufacturers of Drylok® products recommended that we remove the old paint completely by wire brushing or sandblasting and then apply Drylok Masonry Waterproofer. As in any painting job, surface preparation is the most important step. Drylok Fast Plug will be used to patch holes and cracks. Other Drylok products

include Double Duty Sealer; Cement Paint; Clear Masonry Sealer; Masonry Crack Filler; Latex Concrete Floor Paint; Concrete Patch; and Silicone water repellent. If you have basement seepage and want to do a complete job of masonry waterproofing, remember that a wet wall is a symptom, not the problem, so look for the cause. Check for leaky downspouts or gutters, blocked drainage pipes, improper grading or anything that causes water to run off towards foundations. Correcting these, plus applying Drylok Masonry Waterproofer to the walls, will give you the best results.





Technical examination, including microphotography, at right, showed wood pattern was telegraphed, a few wood fibres were embedded, pitch and debris attached, mildew was present, the bottom film was alligatored, the paint was brittle and can no longer flex. The house will need careful surface preparation before repainting with Olympic Primecoat™ and Olympic Overcoat®.



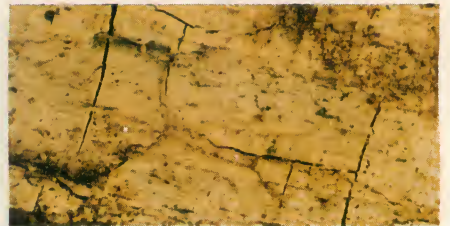
The old wooden porch columns have also deteriorated badly over the years. They will be removed entirely and replaced with durable Old South aluminum columns that will harmonize with the redesigned front. Other Old South columns will grace the breezeway at the back of the house.

Elegance, Grace and Beauty are Lasting Qualities of Old South Aluminum Columns

In the "Old South" collection of architectural columns by Moultrie Manufacturing Company, the traditional elegance of columned porches has been duplicated in aluminum.

Old South aluminum columns add beauty to your home or other building without the cost and maintenance problems of wood. Far stronger than wood, these columns last for generations. They are easy to install, easy to maintain at low cost, resist weathering, insects, warping and dry rot.

Columns enhance modern as well as period homes, projecting enduring strength and beauty, an elusive blend of form and function. Old South columns come in three classic designs that have the look of traditional wooden columns. Moultrie produces them in round, fluted style or in two simple square columns: the Standard size with grooved sides to simulate planking and the Plantation style with recesses in each side and beveled capitals that enhance their charm. Sizes range from 5" in diameter to the new monster 36" diameter in the round style. Plantation sizes range from 6" to 12" and square columns range from 3" to 12".



For a Quality Finish, Start With Quality

When we examined the exterior of our older home, we found what you might expect: extensive peeling and cracking of the paint, and areas that needed structural repair.

To ensure a long-lasting quality finish, we called the Olympic Paint and Stain Company and asked for their help and advice on this project regarding proper surface preparation steps and product selection and application.

Why did we call on Olympic? Because, over the past 50 years, Olympic has earned a reputation for producing high-quality paints and stains. Homeowners, painters, builders, remodeling contractors, designers and architects choose Olympic products because of this quality.

Olympic recommended the following steps to prepare the exterior of an old weathered home for painting:

1. Clean and prepare the surface. Before opening a single can of paint or stain, it is important to remember that a properly prepared surface is the key to long lasting results. Take the time and necessary steps to create a clean, sound surface free of loose paint, dirt, wood fibers, grease, mildew and chalk. You'll be time and money ahead in the long run.
2. Once the surface has been cleaned and is thoroughly dry, apply a base coat of Olympic Latex Primecoat™. This provides a sound base for the top coat application, extends the life of the finish coat, resists mildew and protects against extractive bleeding.
3. After all necessary surface preparation steps are completed, you are ready for the final top coat. For this project, Olympic recommended Olympic Overcoat® for the house and accent trims. This product is backed by a 15 year guarantee and is specifically formulated to provide the very best durability and protection when applied to previously painted surfaces.

Look for Olympic's step-by-step surface preparation recommendations and product selection and application tips in the upcoming Home Remodeling Guides.

OLD
SOUTH

Aluminum Columns

Moultrie
Manufacturing Company

P.O. Box 1179, Dept. PSG3
Moultrie, GA 31776-1179
Toll Free 1-800-841-8674
In Canada 819-822-2422

Front Elevation



Coming: A New Lifestyle and More Room to Live, Work and Grow.

These front, side and rear elevations show new additions: a study added to the living room, a new great room back of the kitchen area, a new deck and breezeway and a new garage.

Among the other products in the next two issues: Olympus® Infinity Super Zoom 300 Camera, Simple Green cleaners, doors by Wing Industries, Glidden Spred Satin® Interior Latex Paint, Minwax® Wood Finish, and Wilsonart® brand laminated plastics. Concerned about energy costs, we asked the American Gas Association for help. They recommended new, clean, high-efficiency gas products. We chose a Tappan Gas Range, Lennox® Pulse™ Gas Furnace and Power Saver Air Conditioning, and Valor® Homeflame Gas Fireplace™.

New roofing will be by Owens-Corning Fiberglas®. A Black & Decker® Security System and Kwikset® Locksets will provide protection and the house will be insured through Allstate®. Contractor, subs and workmen will use Skil® Power Tools and Daubert Easy Mask® Painting Tape.

There will be plenty of yard and garden uses for an Isuzu Pickup, Husqvarna® chain saw, Junior Tomahawk® chipper/shredder, Honda lawn mower and trimmers with new heads by Weed Wizard. The new owner plans to install a Raindrip® underground irrigation system with timer by RainMatic®. For music, there'll be waterproof exterior Omnispeakers® by Paramount Pictures Corp.® and a new Sakcrete® driveway will lead to a new garage, sided with Temple-Inland's Ultra-Lap®.

The new rear deck will be protected by Olympic Deck Stain and exterior sheathing will be supplied by the American Plywood Association. A Hot Spring Spa® will add livability, while a U.S. Gaslight fixture in front of the house will welcome visitors while fitting in with the beautifully renovated neighboring homes.



Rear Elevation

Side Elevation



Garage

The Closing

In real estate, "closing" means the transfer of property from seller to buyer. Before it can take place, all of the terms of the contract must have been carried out, including inspections, searches, surveys and examinations. Just remember to bring your checkbook and your patience. There may be unforeseen charges and there are many documents to sign.

It's a good idea to get a detailed list of expenses beforehand so that unexpected charges will not hold up the closing. Don't be afraid to ask questions of the Realtor®, broker or attorney.

Now is the time to make sure that all of your requirements have been met. In turn, the lending organization should have completed its credit report on your financial standing. The bank appraiser will have examined the house and the Realtor® will have supplied a copy of the contract and the listing. Any changes in the original contract should be initialed and witnessed before the contract is signed by both parties.

What You Can Expect to Happen at Your Closing

Normally, all of the following events will occur at the closing:

1. The title search, survey and deed are examined for accuracy and to clear up any potential problems or objections.
2. Taxes and other charges are divided on a pro-rata basis.
3. Proof of adequate insurance is presented by the new owners to the lender.
4. A new mortgage is issued to the buyer and the old mortgage is paid off.
5. After the brokerage fee (generally 6 or 7 percent), mortgage payoff and other closing expenses are paid by the seller, the seller receives the balance due for his equity and the buyer receives the deed to the home.
6. Necessary recording fees are paid and the seller turns over the house keys to the new owner.

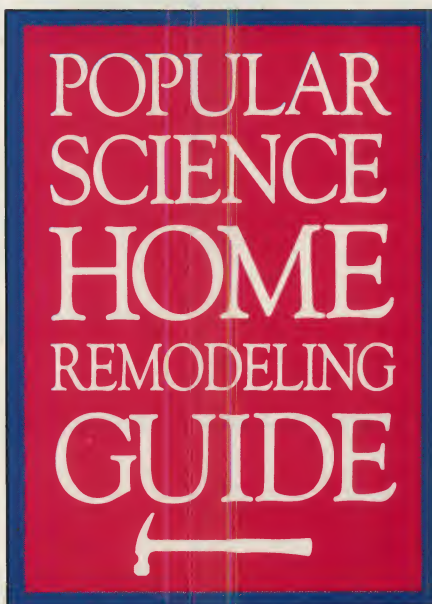
Cover Yourself Legally and Carefully

You should have a lawyer present at the closing. Sometimes the Realtor® may suggest an attorney or the lender may suggest one, but make sure you have competent legal advice. Hiring your own lawyer is generally recommended as a good investment. Set the fee in advance to avoid surprises, and don't be afraid or embarrassed to ask questions. Above all, as the conclusion to a long and careful search, spend the necessary effort to check everything one last time—from appliances included to zapped termites.

At some closings, an escrow agent handles the transfer in its entirety and sends the completed documents and follow-up report to the buyer. This agent can be the lending institution, title company, escrow firm or attorney.



The first planning and preparation steps have now been completed and workmen are just starting to prepare the exterior surface and remove interior partitions. Remember...this is to be continued!



It's Not Too Early for Insurance

Certain kinds of homeowner insurance are needed even before the closing. Later on, you'll want a full homeowner's coverage plan including fire, theft, flood damage and other catastrophic protection. Make sure you're insured for the full replacement value, not for your original buying price, especially after you have improved and remodeled the property.

Most lending institutions require that you bring a copy of the paid hazard insurance policy to the closing.

Don't treat insurance casually. It's far too important for that. The premiums represent a small cost for the peace of mind you'll gain. Sometimes, you can save money by placing your auto insurance with the same company that's insuring your home. For example, in many states, Allstate Insurance Company offers a discount of up to 15% on your auto insurance, if you are an experienced driver with an excellent driving record, and carry a primary homeowners, condominium, or mobile home policy with them.

Win This House Sweepstakes

Popular Science is running a nationwide sweepstakes to tie in with the Home Remodeling Guide. The Grand Prize is THE REMODELED HOME, the same one featured in this special section, OR \$100,000 IN CASH.

Entry forms and details are available at participating hardware stores, home centers, Isuzu dealerships and many other retail outlets across the country, or by writing to: Win This House Entry Request, P.O. Box 3063, Syosset, NY 11775-3063. Requests must be received by June 30, 1989. There is no purchase necessary to enter the sweepstakes. You could also win an Isuzu Trooper, an Isuzu Pickup or a host of other valuable prizes. Many stores listed in the "Where To Buy Section" at the back of this issue are displaying the sweepstakes; the sweepstakes runs from March 1, 1989—July 31, 1989. You can also look for an entry form in the June issue of *Popular Science*.

**Follow along...
pick up helpful advice...
enter and you may
win a prize!**

WHERE TO BUY LISTING

Look for the products featured in "The Home Remodeling Guide" at the stores listed below.

ARROW FASTENER CO. INC.

Available at leading hardware, home center, lumber, discount and warehouse stores including:

Ace Hardware Stores
Builders Emporium
Builder's Square
Dixieline Lumber
Ernst Stores
Hardware Hank Stores
Home Club
KMart
National Lumber
Orchard Supply
Pro Hardware Stores
Sentry Hardware Stores
True Value Stores
Trustworthy Stores
Wal Mart

MARVIN WINDOWS and DOORS

CALIFORNIA

Anaheim • Sterling Pacific Bldg. Products
Bakersfield • Sandstone
Berkeley • Ashby Lumber
Berkeley • Truit & White Lumber
Burlingame • Burlingame Glass
Campbell • Firehouse West
Concord • Dolan's Lumber
Concord • Simons Hardware
Dublin • Elegant Door Company
Fresno • White Pine Lumber Distribution
Merced • San Joaquin Glass
Mt. View • McCleod Glass Co.
Oroville • Ron Wakefield Glass
Pacific Grove • Brad's Glass
Pleasanton • Simons Hardware
Rancho Cordova • Collier Warehouse
Sacramento • Halberg, Inc.
Sacramento • View Points (Dorris Moulding)
San Carlos • The Glass Studio
San Carlos • W.J. Bank Glass
San Francisco • Collier Warehouse
San Jose • The Screen Shop
Santa Cruz • Fire House West
S. Lake Tahoe • South Shore Glass
Tulare • Lampe Lumber
Visalia • Eli's
Walnut Creek • Simons Hardware

OREGON

Corvallis • Twin Pines Lumber Supply, Inc.
Eugene • Midgleys Glass
Portland • Powell Door & Lumber Co.
Portland • Truax Builders Supply

WASHINGTON

Gig Harbor • Borgen Building Supply, Inc.
Kelso • Baker Lumber
Port Angeles • Everwarm Building Products
Tacoma • Vaughan's Building Center, Inc.
Tacoma • The Washington Window Co.
Vancouver • Star Building Materials, Inc.
Wenatchee • Community Glass

TECHSONIX CORPORATION INTERNATIONAL-USA

CALIFORNIA

Gardena • United Overseas Supply Co.
Los Angeles • Bavarian Masonry

THRESHOLD TECHNICAL PRODUCTS

ALL STATES

Threshold Technical Products
11325 Reed-Hartman Highway
Cincinnati, OH 45241
1-800-458-4931

Troy-Bilt TOMAHAWK® Shredders

CALIFORNIA

Sacramento • Troy-Bilt Factory Store

OREGON

Portland • Troy-Bilt Factory Store

UGL® manufacturers of Drylock® Waterproof

ALL STATES

Ameritone Paint Stores
Anawalt Lumber Stores
Lumbermens Stores
Orchard Supply Stores
Sinclair Paint Stores
Vista Paint Stores
Western Lumber Stores

CALIFORNIA

Alameda • Paganos Ace Hardware
Cathedral City • Decratrend
City of Industry • California Hardware Co.
Commerce • Dunn Edwards
El Cajon • Paint Plus
Glendora • Village Color Center

NEVADA

Las Vegas • Decratrend

OREGON

Myrtle Creek • Del's True Value Building Supplies
Portland • Builders Square

WASHINGTON

Bellingham • Morse Hardware
Bellvue • Preservative Paint
Linwood • Preservative Paint
Seattle • Builder's Square

YAMAHA PRO - 4 DEALERS

CALIFORNIA

Anaheim • Active Kubota Inc.
Alhambra • Alhambra Yamaha
Arvin • Bear Mountain AG Hardware, Inc.
Colusa • Colusa Tractor Co.
Concord • Concord Yamaha
Corona • Sunwest Cycles
Fontana • John Burr Cycles Inc.
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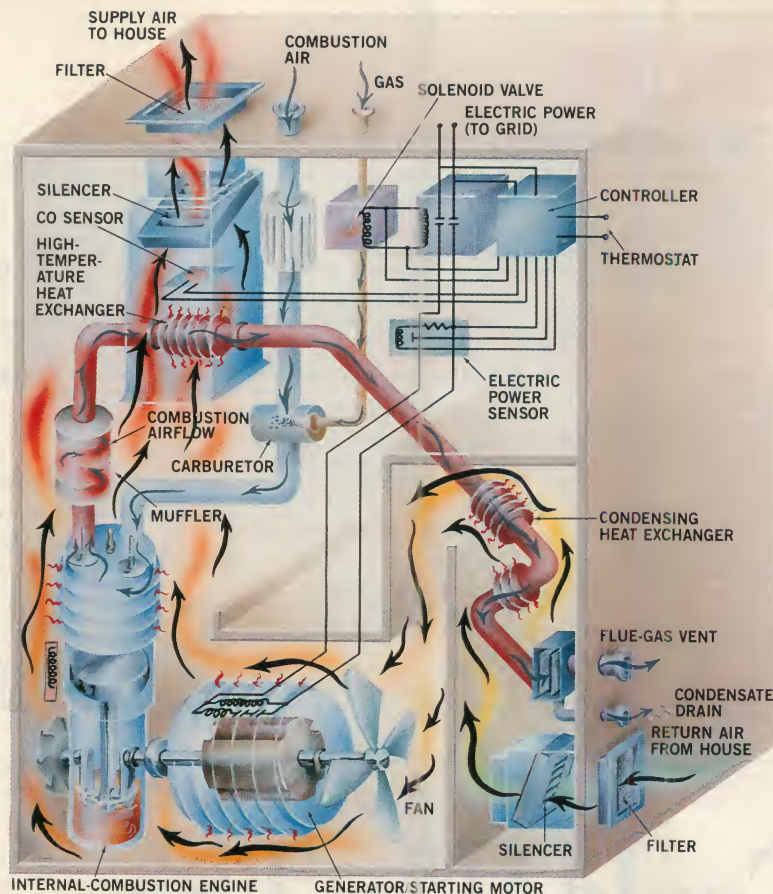
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DRAWING BY BOB LANGE

A five-hp internal-combustion engine, adapted to burn natural gas, drives a generator, and waste heat from both is recovered to heat the house. Here's how it works: Combustion air and fuel enter, mix in the carburetor, and the mixture flows down to the engine's single cylinder, where the spark plug ignites it and it burns conventionally. That drives the piston, turning the shaft of the induction generator (which doubles as a starting motor for the engine—see text), thus producing electricity.

On the other end of the shaft is a fan. It draws in return air from the house, blowing it past several sources of heat. The first of these is the condensing heat exchanger near the end of the exhaust pipe. There, combustion gases from the engine are cooled enough to condense and release much of their latent heat, which is transferred to the airstream passing around the pipe. The warmed air next passes over the generator, absorbing waste heat, then over the outside of the engine, where it gathers more waste heat. Finally, it flows over the machine's high-temperature heat exchanger and out into the ducts of the house.

motor. When your house thermostat calls for heat, the cogenerator's control system routes power from the electric grid to start the motor; it in turn cranks the engine. Once the engine is running, the motor becomes a generator pumping out electricity to satisfy household needs and sending any excess back into the grid.

Waste heat—from the generator, engine, and exhaust gases—is then transferred to the supply airstream and channeled through the ducts to heat your house.

Bettering the best

Wicks started thinking about replacements for the home furnace during the energy famine of the mid-'70s. But all his concepts were upstaged when the first condensing furnaces were introduced in the early 1980s. These are so efficient because they condense the water vapor from the flue gases and capture the latent heat [Sept. '82, March '83].

"Most people would assume that if you're almost one-hundred-percent efficient you can't do any better," Wicks relates in reference to condensing furnaces. "But in thermodynamics, not all energy is of equal value. Specifically, mechanical and electrical energy are more valuable than heat energy," he continues. "About four times more valuable."

His rationale?

"The central power plant must use 100 units of fuel to deliver 25 units of electricity to your house. The plant is losing 65 units up the stack and into the river and another 10 units get lost

Continued

Home-size cogenerator

Like the most efficient of today's furnaces, this prototype condenses flue gases to capture most of the energy in the fuel it burns. Unlike any furnace, however, this one also can light your lights and run your TV set.

By V. ELAINE GILMORE

Dr. Frank Wicks, professor of mechanical engineering and thermal sciences at Union College in Schenectady, N.Y., would like to outlaw the home furnace. He'd even relegate to the scrap heap the new condensing furnaces, those super-efficient heaters that capture 90 percent or more of the heat in the fuel they burn—not good enough in Wicks's book.

He'd replace every furnace with a cogenerator, a machine that produces

heat and electricity. Though most existing cogenerators are big commercial affairs, Wicks has invented a small one for homes. It converts 20 percent of the energy in the fuel it burns to electricity. Then it captures about 95 percent of the remaining energy to heat your house. That, figured Wicks's way, makes his machine nearly 160 percent efficient. More about that later.

Essentially the little cogenerator is an air-cooled single-cylinder engine modified to run on natural gas or propane, and coupled to an induction

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Road & Track, Nov. 1988



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Laboratory Tests*

Model	Sensitivity, dBm/cm ²	
	X-band	K-band
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Audiovox RX-4	104.1	93.9
Cincinnati Microwave		
Escort	112.9	106.8
Cincinnati Microwave		
Passport	114.1	107.8
Cobra Trapshooter		
RD-3170	113.4	110.8
Fultron 15-0900,		
Snooper D-4000	109.4	108.8
Kraco KR-16	102.7	104.7
Mascot PH222	101.5	94.6
Maxon RD-25	109.3	106.8
Radio Shack Micronta		
Road Patrol XK	107.6	106.0
Uniden RD9XL	113.1	108.8
Whistler Spectrum 2	115.6	110.4
Average unit	110.1	106.3

Source: Road & Track, Nov. 1988

*Conducted by Advanced Product Evaluation Laboratory, Inc.

BEL VECTOR 3 is the only unit in this test that also detects Ka band radar.

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Home-size cogenerator *Continued*

in transmission. Based on that, it's valid to say that electricity is worth about four times more than heat.

"With my system if the homeowner buys one hundred dollars worth of fuel and converts twenty dollars worth to electricity, he has eighty dollars worth of electricity. And from the remaining eighty dollars worth of fuel the system captures ninety-five percent of the energy, or seventy-six dollars worth of heat. Therefore the delivered value of the product is one hundred fifty-six dollars." Wicks likens that to an effective efficiency of nearly 160 percent.

He has patented the machine in the United States, Canada, and the Soviet Union and has patents pending elsewhere. "There's a use for it wherever you have cold weather and natural gas," he says. The prototype, paid for with a \$70,000 grant from the U.S. Department of Energy's Office of Inventions and Innovation, is 16 by 40 by 20 inches high.

Power output is about three kilowatts at 15 amperes. That's large enough to supply a typical house with heat and electricity in winter, Wicks says. When the furnace is off, no electricity is produced. When it is producing more than the house needs, it would either make the electric meter run backward or, more likely, feed electricity back into the grid through a separate meter. (Done that way the utility can pay less for the electricity it buys than it charges for what it sells.)

More for less?

Wicks thinks his cogenerator can sell for less than a condensing furnace. He's convinced it ultimately can be sold for under \$1,000 (plus installation).

That's a fraction of the price of current small cogenerators ["Baby Cogenerators," Oct. '86]. The Wicks machine is of considerably smaller capacity. "And it's a much simpler machine," he explains. A key reason for its simplicity: It uses an air-cooled engine while other cogenerators use liquid-cooled engines. Another reason is that most parts do double duty. "The exhaust stroke of the engine forces the fuel gases out—so no purging fan is required," Wicks points out. "When the engine is not running, the valve acts as a flue damper. And the cooling blower on the generator shaft also circulates air to the house."

Furthermore, this is an induction generator: The electric utility supplies the energy to start the motor and provides speed and voltage control. Synchronous generators, the other kind, need extra gear to do all of those things themselves. (Their advantage is that they can run in a blackout while an induction generator cannot.)

Two companies, Hartford Manufacturing in Cobleskill, N.Y., a maker of propane equipment, and Dhorb Co. of Scotia, N.Y., in the refrigeration business, recently licensed the technology from Wicks. Now each is working on a preproduction prototype.

A way to go

"It's a simple idea in theory, but it's not so simple to put into practice," reports Cole Vickary, general manager of Hartford Manufacturing. The first problem that must be solved is basic: "We have to get the motor and generator together on a baseplate with a coupler that'll stay together. The original model couldn't run for more than five minutes without self-destructing."

Then the developers have to reduce the noise and vibration. Lester Lee, an invention coordinator at the Department of Energy, says the present prototype sounds (and shakes) like a large lawn mower. "When Wicks turned it on we could barely hear each other," he reports.

And they have to find an air-cooled engine that will run long enough and reliably enough without costly maintenance. "That's probably the major challenge," says Vickary. "And it's why most of the people who have gotten into cogeneration use water-cooled engines."

There are safety concerns that must be addressed. "With exhaust gas you always have carbon monoxide present," notes Howard Robb, chief evaluator for the Office of Energy Related Inventions of the National Institute of Standards and Technology (formerly the National Bureau of Standards), which recommended the Wicks cogenerator for Department of Energy support. "So you have to ensure that there is no leakage of exhaust gas into the house airstream." Wicks's design includes a carbon monoxide sensor that would shut down the system if the concentration got too high.

There also may be political concerns, Vickary points out. "By law the utility has to allow you to hook into the grid. But there are a lot of gray areas. My customer is going to say, 'Who do I see to do that, where do I get the permits?'"

Vickary is talking about a long-term development effort with a product available maybe 5 or 10 years down the road.

Marshall Clarke, president of the Dhorb Co., has in mind a shorter time frame. He's aiming to submit a prototype for American Gas Association certification by late this winter.

When might you be able to buy one for your basement?

"Early 1990s," Clarke predicts. **ES**

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What's News

Micro revolution

The astonishing micromotors shown on our cover this month are actually much smaller than the scale shown in the microphotograph. As Robert Gannon's article explains, the motors are only two-thirds the width of a human hair and "some 10,000 of them could fit into a pea." Why do we need such tiny motors? Even the scientists who invented the mini marvels don't know all the answers yet. But there's a strong feeling that micromotors are the most revolutionary development since the invention of integrated circuits. For a full report on this important development, turn to page 88.

Plastic auto wheels

The Shelby Shadow, a limited-edition performance version of the Dodge car, is available with styled composite wheels. The wheels are made by Motor Wheel Corp. (Lansing, Mich.). It's the first use of this type of plastic wheel in a car in the United States. We first told you about this development in "New Steel-Tough Jobs for Plastics in Cars" [July '85].

Second smart house

A consortium of electric utility companies has announced plans to build an Electric Smart House. It will be located next to the National Association of Home Builders Gas Research Institute Smart House in Bowie, Md. "The Electric Smart House will revolutionize the capabilities and function of future houses," says William McCollam Jr., president of the Edison Electric Institute, which organized the consortium. The EEI says the prototype house will have an exceptional level of energy efficiency and an integrated computer network. The house will have a super-insulated outer shell and a computer-controlled network of appliances.

Another unique feature of this home is the "gateway" device, which allows homeowners to control their energy spending precisely. The gateway, or interface, allows a homeowner to determine the lowest-cost energy peri-

ods of his local power company. The homeowner can then run big energy-consuming devices during low-cost periods—leading to lower utility bills.

All these benefits will be accomplished with a simplified wiring system for the house. Instead of separate wiring for electricity, cable TV, telephone, and security-alarm system, the house will have a single integrated cable for all these systems.

Smokey's silver anniversary

Three hundred months ago a new feature appeared in POPULAR SCIENCE—a "clinic on cars" by Smokey Yunick. And "Say, Smokey—" has been a nonstop performance in POPULAR SCIENCE ever since. In the March 1964 issue America's most famous mechanic—then and now—answered 10 questions from readers about problems they were having with cars. Smokey has answered thousands of readers' questions since then. At the same time Smokey has run a famous truck dealership in Daytona Beach, Fla., where he lives; acted as an engineering consultant to major Detroit car manufacturers; traveled frequently to remote South American jungle locations to trouble-shoot oil-well pumping engines; and served as a one-man lobbying organization for simplicity in automobiles.

Nowadays "The Best Damn Garage in Town" is really an independent research and development laboratory. It has chassis and engine dynamometers, a flow bench for measuring engine breathing, and a complete machine shop for making prototype parts. Smokey has all the basic tools needed to develop and refine engine designs.

Recently Associate Editor Stuart F. Brown and photographer John B. Carnett spent two days with Smokey, engaging him in a rambling marathon conversation about all the aspects of the modern automobile.

Smokey is just itching to finish his work on his newest adiabatic engine. He has spent 35 years developing it, and his goal is to see the design used in production automobiles. Smokey has an unshakeable conviction that gasoline can be used far more efficiently

than it is at present. This special Smokey story begins on page 105.

Measuring forests

A team of scientists from the University of California, Santa Barbara, is about to embark on a project to measure the forests in the eastern United States. "Despite its importance, no statistically valid estimates exist for the amount of organic matter contained in any major vegetation type throughout the world, including forests," says Professor Daniel B. Botkin, who heads the new study with his associate, Lloyd G. Simpson. Botkin's study could help in predicting global-warming trends that may result from the buildup of carbon dioxide in the atmosphere. The UCSB scientists say that current estimates of organic matter in eastern forests are based on subjective expert guesses. Botkin's measurements of other forests have shown that such guesses can be seriously misleading.

Any-fuel engines

Last month we told you about a new variable fuel control system General Motors is developing. With the new system an engine can burn a variety of fuels. Now it has been announced that GM will supply 2,220 Chevrolet Corsicas and Luminas to test methanol as an alternate fuel using the new system. The Lumina, due on the market later this year, is a four-door version of the GM-10 chassis used in the Buick Regal, Oldsmobile Cutlass, and Pontiac Grand Prix coupes. The test will help GM learn how methanol fuel performs under real-world conditions, says GM President Robert C. Stempel. What happens if you run low on methanol with the new cars and can't find a station to refill? No problem. The cars also burn gasoline or a mixture of methanol and gasoline.

Herbert Shuldhine
Editor

MICROMACHINE

Microscopic motors, mass-produced with other mechanisms on silicon wafers, promise a revolution in tiny machines. These micromachines could supply "muscle," while micro-electronic circuits integrated with them provide "brains." Potential uses—barely envisioned at this stage—include medical and manufacturing gear, plus scientific instruments.

By **ROBERT GANNON** *Photos by Marc Geller*

It's after midnight this Friday, June 27, 1988, and lots of students are out on the town. But graduate students Long-Sheng Fan and Yu-Chong Tai—in blue jeans and T-shirts hidden by white smocks, medical caps, and surgical gloves—are in the fourth-floor microfabrication lab in Cory Hall at the University of California at Berkeley.

It's quiet here, almost lonely, with only the hum of the air-filtration system, a few clickings of automatic equipment, and an occasional shuffle of clean-room booties. Neither student notices the time. They don't care anyway. And they certainly wouldn't rather be out drinking beer somewhere in Berkeley.

Now, at 2:07 a.m., they're finally ready. Fan slides off his stool and stands up, concentrating. Apparatus in place, he carefully touches probes to two terminals leading to the armature of a stepping motor. He turns up the voltage: 20, 80, 100.

Suddenly the rotor—with its six spokes, it looks like a snowflake—jumps. So does Fan. He touches a second set of terminals, and the rotor painfully jerks another step. Then the students set another rotor in position and place a video camera to record its belabored, twitching rotation.

Ten days later, at a prestigious Institute of Electrical and Electronics Engineers (IEEE) conference at the plush seaside resort of Hilton Head, S.C., Fan plays the tape over and over to engineers and scientists crowding around a TV set. The interest is intense. As one gray-haired engineer who looks as if he's seen it all says with only a trace of self consciousness: "This is little like the Wright brothers' flight."

Smaller than a human hair

The reason for the excitement is the size of the motor—only about two-thirds the width of a human hair. Some 10,000 of them could fit into a pea.

For the last three days the conference members—representatives from industry and academe—had been listening to mind-charging reports in the new field of microfabrication, the sculpting of objects so tiny you can see their shapes only under a microscope ["Micromachines," June '84].

Then the Berkeley students came along with proof that a rotor the size of a fly's foot can be driven by an electrical current. And that perhaps climaxed the whole conference on micromachines.

What the new microengineers are doing is taking the technology of microchip building and changing the objective: Instead of fashioning devices that simply shunt electrons, they're sculpting tiny objects designed to move—diaphragms, springs, sliders, cantilever beams, gears, and

now driven rotors. Integrated-circuit (IC) technology is essentially two-dimensional. Micromachining works in three. Those in the field call traditional IC people "flatlanders."

The field is so new it hasn't even got a proper name—microtechnology or micromechanics or micromachining, depending on whom you ask. But the excitement is palpable, and the implications, say those involved in it, staggering. As electrical engineer Bob Bower of the University of California at Davis puts it, "I haven't felt this much excitement for twenty-five years, not since the early days of integrated circuits." Says George Hazelrigg of the National Science Foundation, "We are talking in terms of a revolution."

The movement began in 1981, when transducer experts attending a Boston conference gathered to talk about what they saw as an emerging field of micromachining. It coalesced the next year, when Kurt Petersen, then with IBM's research division in California (and now executive vice president of NovaSensor, a Fremont, Calif., company devoted to microstructures), wrote an IEEE paper summarizing the field.

Motor milestone

The Fan-Tai motor is just the latest step. "The important thing with this motor," says lithe, energetic Richard S. Muller, the students' adviser and director of the newly named Berkeley Sensor & Actuator Center, "is that now we know a rotor this small can work. We had no proof before. It's a true milestone; the future now is closer."

What is the future? Blurry. But late at night, when conference scientists and engineers relax at a Hilton Head tavern, they shed some of their cautious reserve, and they look ahead a decade or two. They see machines tinier than flyspecks—little robots swarming by the thousands—cleaning, exploring, repairing. They see minute mechanical creatures fashioned from single crystals of silicon: workers that will swarm over the skin of a submarine, scouring; that will pour into the inside of a reactor, inspecting; that will flood a person's bloodstream to slash away cholesterol deposits—and when their energy runs out, will simply flush away, unnoticed, through the bladder.

"The thing is," says NovaSensor's Petersen, "we don't really know where all of this will take us. We're only sure that we're in the middle of inventing a whole new industry."

Others agree. The London-based market-research firm Mackintosh International estimates that only one year from now micromechanics will be at least a \$630-million industry. *Business Week* claims that soaring interest has far outstripped the supply of engineers in the field. And

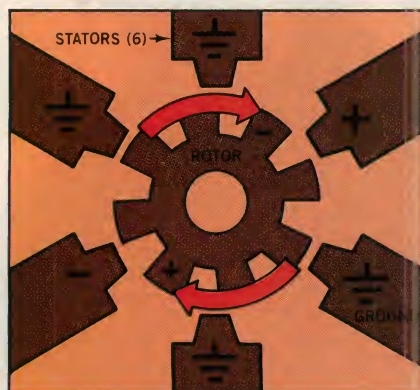
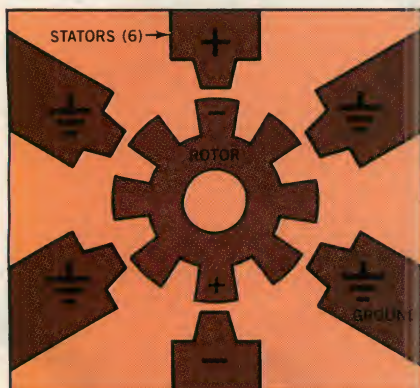
Continued

MAGIC



Microtechnology researchers Richard Muller (left), Yu-Chong Tai, and Long-Sheng Fan (front) wear protective clothes to minimize contamination of tiny mechanical components developed at the Berkeley Sensor & Actuator Center, University of California. A silicon chip they fabricated with 16 micromotors on its surface is compared with the head of a pin (above right). Close-up of the first electrically powered micromotor, which was developed by the team, reveals its nearly flat structure (left). The central eight-arm rotor is about 0.002 inch across, with rotor arms no bigger than red blood cells.

HOW MICROMACHINES WORK: A SAMPLING OF TINY MECHANISMS

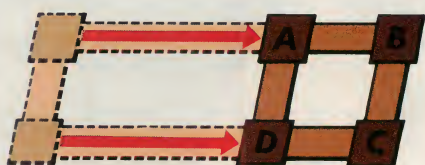
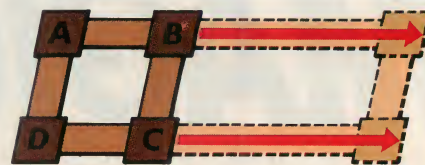


MICROMOTOR

Electrically powered micromotors are driven by electrostatic forces between motor elements, not the magnetic fields used in most conventional motors. In a design from the University of California, Berkeley, the whole motor is about $\frac{3}{1,000}$ of an inch in diameter. To drive the micromotor, negative and positive voltages are applied to two stator poles 180 degrees apart (top). Four remaining stators are at ground or zero electrical potential. The positive and negative stator voltages induce opposing charges on the rotor poles nearest the stator poles. Next, the negative and positive voltages are shifted clockwise or counterclockwise to the next set of opposing stators. The four remaining stators are now grounded (bottom). As a result, the positive potential on the stator attracts the negatively charged rotor pole while the negative stator attracts the positive rotor pole. The rotor continues to spin as stator potentials are switched the same way.

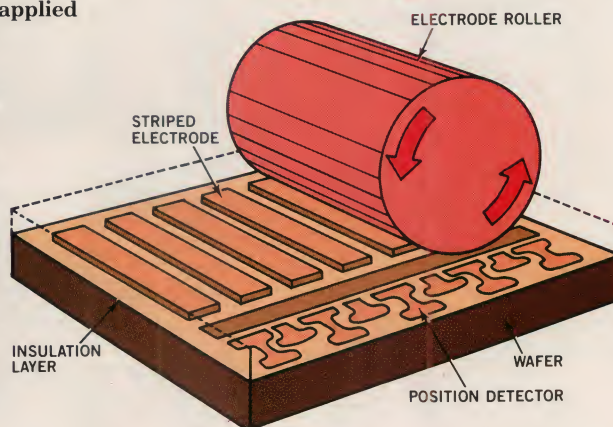
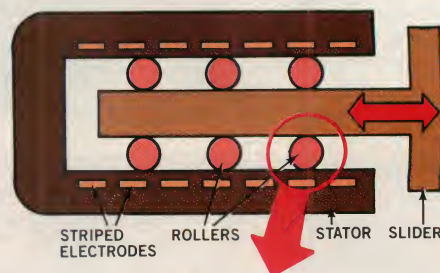
INCHWORM

One technique of adding mobility to tiny machines has been developed at AT&T Bell Laboratories. An "inchworm" device uses piezoelectric-ceramic bars that physically stretch and shrink as voltages are applied and removed. The bars, arranged in a small square, have four silicon feet, labeled A, B, C, D (top). To make the device move along a silicon or other metal surface, feet A and D are anchored in place by applying a voltage between them and the coated silicon base. When other voltages are applied across thin metal layers coating bars AB and DC, they lengthen, advancing feet B and C (middle). Then feet B and C are anchored, feet A and D released, and the voltage across the bars is shut off. The bars then shrink, pulling feet A and D forward (bottom). By repeating the sequence, the tiny device advances over a surface.



LINEAR ACTUATOR

A linear actuator moves a slider arm back and forth. One actuator developed in Japan is powered by electrostatic forces and has cylindrical electrodes free to roll between the slider and striped electrodes (top). A voltage applied to a striped electrode near a cylinder produces an electric field. The electrostatic force attracts the roller, advancing it and the slider in either direction (right). The first striped electrode activated is discharged and voltage is applied to the next electrode in the roller path, continuing the movement. Voltages are applied to activate all the rollers at once.



now a select panel assembled by the National Science Foundation (NSF) reports that "mechanical assembly is at the same stage that electronics was thirty years ago... ready for a revolution in technology and size." The panel calls for a \$50-million national laboratory for microdynamics development.

On the other end of the scale, NSF's Hazelrigg foresees the cost of motors like the Berkeley prototype as only one-tenth of a cent each, perhaps less.

"And that's the exciting thing," adds Kaigham Gabriel, an electrical engineer with AT&T Bell Laboratories' Machine Perception Research Department. "The important thing is not necessarily that these assemblies are small, but that they can be put on wafers by the thousands, and that wafers can be produced by the hundreds."

Whoever masters the techniques will have an enormous head start on what is being called the new generation of micro devices. Japan, Europe, and the United States are

racing to be first. So far, the United States is ahead.

Because the key sculpting process isn't radically different from the building of microelectronic elements and the essential techniques can be simply copied, the coming industry is expected to arrive swiftly.

Working with now-standard methods of producing microelectric circuitry, the new engineers etch patterns on semiconductor wafers, and then by selectively depositing and eating away the layers, delicately carve bridges and diving boards only a few microns thick—about $\frac{1}{200}$ the diameter of this period. (A micron is one-millionth of a meter; human hair averages 75 microns in diameter.)

They mainly use silicon. It's astonishingly strong at these sizes—comparable to steel—and because it usually is a single-crystal material, it can flex without fatigue almost indefinitely. And it is piezoresistive. That means that under strain its electrical resistance changes—an extraordinarily useful property for sensing.

Finished products are already being widely used commercially. Speck-sized sensors now detect pressure, acceleration, vapors, temperature, sound, even smells. For instance, Houston's Millar Instruments mounts two pressure transducers, spaced two inches apart, near the tip of a catheter. Physicians thread the assembly into a heart so that the sensors lie on each side of a valve to check the pressure gradient. On the tip of another catheter, Millar mounts a microtransducer that transmits a burst of 20-megahertz ultrasound, then receives echoes from moving blood cells, and through doppler, measures their velocity.

Top-of-the-line autos are using a variety of microsensors—from acceleration detectors for triggering air bags to computerized engine-performance adjusters, and from sensors that tell you your tires are low to those that sneer when you drive inefficiently. Such sensors have become not only elegant, but commonplace.

Clever actuators

Trouble is, they're passive. To develop midsize robots, you need "actuators," micromachines that cause other devices to move. Among the most clever so far:

- The inchworm. Take four tiny piezoelectric-ceramic bars arranged in a square, attach four silicon feet at the corners, and set it all on a silicon wafer with a dielectric coating. An electrical current will make each leg expand or shrink, and by sequencing voltages around the legs, you can force the device to walk around on the wafer. Tom Poteat and William Trimmer at AT&T Bell Labs did just that, and found that the device is accurate enough to align optical fiber precisely.

- Linear actuator. At the University of Tokyo's Institute of Industrial Science, Hiroyuki Fujita fashioned a tiny cylinder and set it atop a microscopic grid of electrodes. When he applied voltage to electrodes on one side of the cylinder, the electrostatic force rolled it forward. When he charged those in back, the cylinder backed up.

- The squid. David Kerns, chairman of Vanderbilt's Electrical Engineering Department, is working on a self-contained free-swimming microrobot. Powered by magnetic coupling from an external coil, it will squeeze itself, squirting itself forward... squidlike.

All innovative. But for "gnat robots," as the people at the Massachusetts Institute of Technology like to call them, you need a fast rotary motor. Three institutions—MIT, Bell Labs, and U. C. Berkeley—are hot on the trail, and all are proceeding along roughly the same paths.

The researchers see rotary micromotors not simply as shrunken versions of conventional magnetic motors, but electrostatic units powered by columbic "static electricity" forces.

For one thing, explains MIT microelectricity expert Ste-

phen Bart, magnetic motors, with their windings, are too complicated to build in micro size. For another, they require magnetizable material—iron or nickel—at this point too difficult to incorporate on silicon chips.

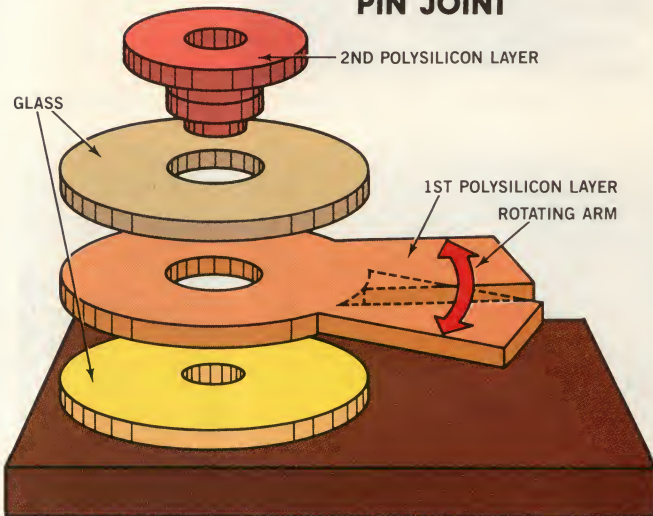
But now that the Berkeley motor can humph and croak around, the next trick is to get it running smoothly. And then come what many see as major problems—but fascinating puzzles that everyone in the field is eager to explore. Says soft-voiced William Trimmer of AT&T, one of those in the forefront of microtechnology: "Physical phenomena on the microscale will probably be as different from our everyday experience as are those on a galactic scale."

At submicron levels, for instance, the concept "flat" or "smooth" means little, for molecules are lumpy, and so are the "edges" of the objects they compose. Air—who knows? It might seem like molasses to micromotors. And friction: Researchers ask what the word friction really means. At these sizes do lubricants lubricate? How does friction relate to bearings? In fact, what kind of bearing?

Berkeley's Muller wonders if his research team has to

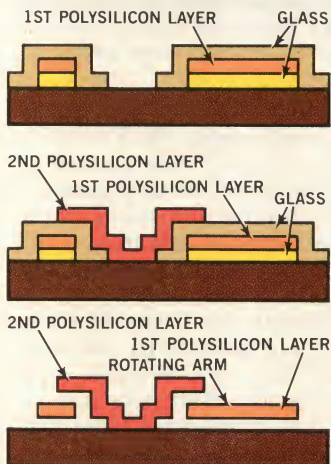
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SILICON THAT MOVES: HOW TO ETCH A PIN JOINT



Creating a pin joint with a fixed hub and a rotating component involves several etching and deposition steps. A layer of glass is first sandwiched between a polysilicon layer and a silicon base. Acid is used to etch a hole through the two upper layers (top). Next, glass is deposited to seal the edges of the hole. An opening is etched through this glass layer

at the bottom of the hole, exposing the silicon base. A second layer of polysilicon—the pin—is deposited and fixed to the base (middle). When the glass layers are etched away, the arm formed by the first polysilicon layer is free to rotate (bottom). Multiple arms would form the rotor of a micromotor. This pin-joint fabrication sequence may take place simultaneously at thousands of sites on a silicon wafer as patterns are exposed through a template, etched, and then recoated.



DRAWINGS BY MITCHELL J. ALBALA

3-D SCULPTING WITH X-RAYS

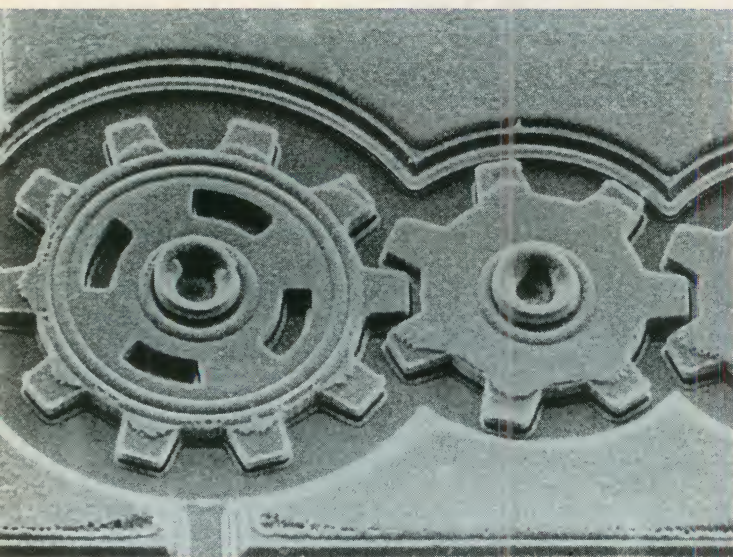


HUMAN HAIR
76 MICRONS DIAMETER

This scanning-electron-microscope photo shows the stunningly successful use of deep-etch X-ray lithography to make 3-D structures. The objects (details of less than $\frac{1}{2}$ micron are compared with a human hair in the drawing) were sculpted by Wolfgang Ehrfeld and his group at Germany's Karlsruhe Research Center.

The technique uses a synchrotron that accelerates electrons and develops high-intensity X-rays. The short-wavelength X-rays blast through a variety of polymer photoresist coatings. While portions of the coatings are blocked by a mask, the radiation breaks up the polymer chains. When dipped in a "developer," what has not been masked is removed. Additional metallic plating and etchings can produce a mold insert for high-volume reproduction by injection molding.

The big drawback now is the cost. Synchrotrons are enormously expensive. That's why the United States has only a handful—two at Brookhaven, another at the University of Wisconsin, one more at the National Bureau of Standards, two under construction.—R. G.



A tiny gear train made at AT&T Bell Labs is powered by a narrow gas stream spinning either of two outer gears.

"Maybe," says Muller, "we don't have to worry too much about frictional wear. At least that's what some new work at Bell suggests."

He's talking about a minute air-driven turbine fashioned by Bell Labs' Trimmer and Gabriel, and fellow researcher Mehran Mehregany. A short while ago, at Bell Labs' Pentagon-size facility in Holmdel, N.J., Gabriel showed me how it works. I found him in laboratory No. 4b-624, in sneakers and dark-gray jeans, hunched over a binocular microscope.

With a pair of tweezers he picked up a tiny chip marked with a dot, then slid it onto the slide stage. The 300 $\times$ magnification revealed the dot to be a 160-micron-diameter gear with notched teeth the size of red corpuscles.

When Gabriel blasted it with a jet of air streamed through a hypodermic needle, the turbine blurred. No wonder. It was spinning at more than 24,000 rpm.

Air support

"You'd expect that thing to have sawn right through the shaft," Berkeley's Muller told me later. "That it didn't is tantalizingly good news." One reason it didn't, Gabriel believes, is that it spins on a layer of air.

MIT's Jeffrey Lang points out two other areas of potential problems: the stability of those spinning rotors, and the control of residual stress (the tendency to warp) in polysilicon layers that must be only a micron or two thick.

And then there's the whole question of power supply. Micro batteries? Tiny, single-crystal solar cells? Pneumatic? Power radiated from elsewhere?

When eventually those problems are solved—perhaps quickly, perhaps not—what do those with vision foresee?

One easy job for a micromotor, says Trimmer, is to chop a light beam, a fiber-optic shutter. Others see medical pumps and gyroscopes. Still others envision full-wall TVs made up of half a million tiny screens controlled by micromotors.

"Or you could build a saw edge into a rotor," says Muller,

[Continued on page 143]

worry about a motor tearing itself apart. "We know silicon's electrical properties well," he says. "Now we need to know its fracture strength, its heat-conducting properties, its elasticity. We have to start thinking in terms of the effects of friction on elements of incredibly low mass—and that's entirely new territory for mechanical study. Right now we're infants, discovering."

"The friction issues are probably the most unknown, probably the most perplexing, and potentially the most devastating," adds MIT's Bart. "As a consequence, most people working on these devices say 'Well, let's just let the rotor drag.' But I'll give you a gut feeling: Somebody clever, with a clever idea—which hasn't yet appeared—will solve it neatly."

Magna fridge

Refrigerators work by harnessing a well-known thermodynamic principle: a gas gets hot when compressed and cools when allowed to expand. Now comes an entirely new principle of refrigeration based on an effect of magnetic fields on certain crystals. It can produce temperatures approaching absolute zero.

By JIM SCHEFTER

I'm staring at one of the world's first magnetic refrigerators, a triangular slab of chemically milled stainless steel lying on a laboratory bench. It looks like something that has been pulled off the front end of a race-car engine. Mounted in the center of the assembly is a wheel.

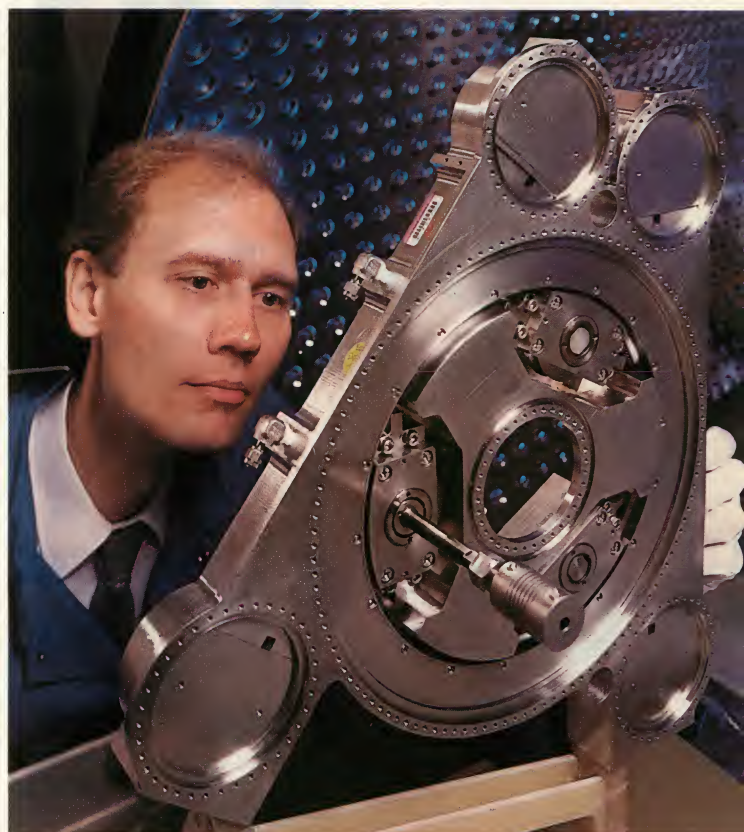
"Some materials heat up when they become magnetized," says Ken Price, a senior staff engineer at Hughes Aircraft Co.'s Electro-Optical and Data Systems Group in El Segundo, Calif. One such material is a clear crystal called gadolinium gallium garnet. The element gadolinium becomes magnetic at low temperatures. In a crystalline compound it gets hotter when magnetized and cools when demagnetized.

Because of the material's properties, it can be used to move heat from one place to another. The crystals perform the same task that gas does in a conventional refrigerator, which works like this: A refrigerant gas is compressed and sent to a condenser, where it's cooled and liquefied. The refrigerant then passes through a valve that allows it to expand to a gas. The expanding gas travels through the refrigerator's evaporator coils, absorbing heat and thereby lowering the temperature inside the refrigerator.

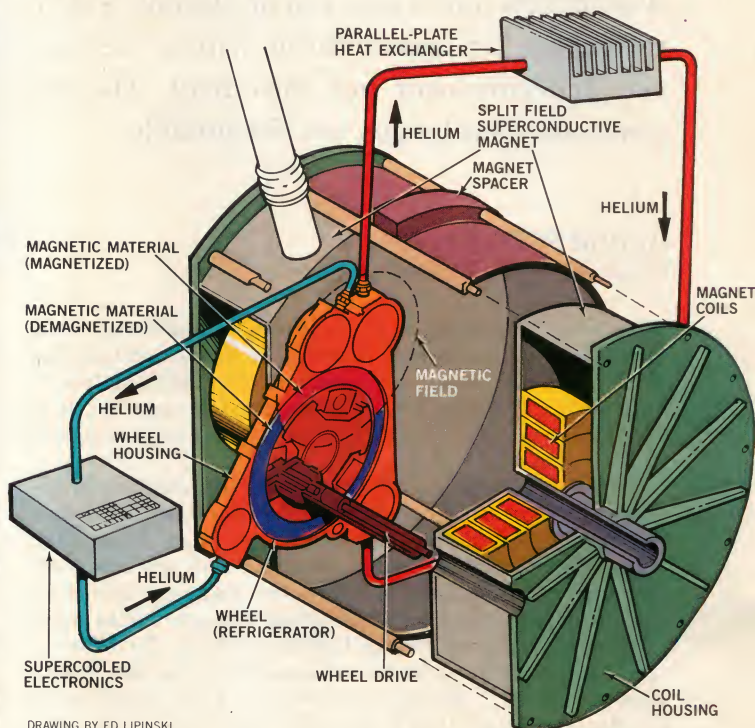
Gas-cycle refrigerators can't get much colder than four degrees Kelvin, though. That's the temperature at which helium—the element with the lowest boiling point—becomes a liquid and is no longer effective as a refrigerant. But the Hughes magnetic refrigerator can reach temperatures that are even colder—close to absolute zero. That makes it ideal for refrigerating the electronics carried aboard spacecraft—like the infrared sensors being developed to study celestial bodies, monitor weather patterns, and detect missile launches. The refrigerator may also be used to cool medical research equipment and supercomputer components. And if scientists are able to develop new materials that are superconducting at room temper-

[Continued on page 143]

More than 800 crystal wafers, made from a material that heats up when magnetized and cools when demagnetized, are bonded to a wheel in the triangular refrigerator, which fits into a slot flanked by two powerful magnets. As the wheel rotates at about 6 rpm, crystals pass through a 60,000-gauss magnetic field covering about 120° of the wheel. They warm up, releasing heat to helium flowing through a heat exchanger. The cooled crystals then rotate out of the field and absorb heat from helium passing through another loop; this helium becomes a super-cold refrigerant.



Hughes Aircraft engineer Ken Price prepares a magnetic refrigerator for cooling tests in a vacuum chamber.



DRAWING BY ED LIPINSKI

ON BASE IN SPACE

A bold step into a new era of manned exploration, the U.S. space station will be the largest structure ever put into orbit. The engineering challenges are formidable.

By **JIM SCHEFTER**

Illustrations by Vincent Di Fate

It's just past twilight in the southern United States when a massive glowing ball, larger than Venus and brighter than the full moon, rises suddenly from the northwestern horizon. Moments later, like puppies trailing their master, smaller points of light, first one, then another, appear in the same celestial track.

Climbing swiftly toward the zenith, the spectacular objects race southeast, dominating the night sky until they fall from view less than seven minutes later. Aboard the larger object, comfortably housed in a pod of spacious modules and nodes suspended below the midpoint of a massive 160-meter girder, eight scientists and astronauts pause a moment to glance at city lights twinkling far below.

If anyone happens to be in one of two cupolas, where windows give a 360-degree view, the eight giant solar panels—four sprouting from each end section of the long



girder—will be sparkling with reflected sunlight. The view from space never loses its thrill, but a moment is all the crew has to spare. There's work to be done to keep the U.S. space station and its racks of experiments and instruments operating.

Inside the smaller objects following about 100 miles behind, no one is aboard to enjoy the view. The pair are the private U.S. Industrial Space Facility and the European Man-Tended Free Flyer, both unmanned labs going about their automated business of producing strange new materials, growing crystals of unearthly size and purity, or simply exposing experimental devices to the microgravity of space.

In fact, there may be only one unmanned factory, not two. In a move to tie space-station funding to the privately built ISF, Congress has delayed and may have inadver-



tently killed the American lab. Its demise would give the European Space Agency a monopoly over automated space manufacturing.

But the space station itself is emerging from its cocoon of planning, and its shape can be seen clearly at last. I talked with experts at NASA in Washington, D.C., at the Marshall Space Flight Center in Huntsville, Ala., where the heart of the station—its living quarters and laboratory—are to be built, and at the Southern California aerospace company where the station's main truss is being designed. Here's what I discovered.

A little more than seven years from now, sometime in the fall of 1996, the drama of Americans living and working full-time in space will become reality. Not everyone is happy. Some scientists and politicians are not convinced that a space station is needed, while others complain that

Orbiting 235 miles above Earth and powered by huge solar panels, the space station will allow U.S. and foreign astronauts to live and work in space on a permanent basis. The first phase will be completed by 1997. Then the station will continue to evolve as new scientific uses arise.

its cost will take funding away from planetary and other missions. Even so, after more than half a decade of designing, revising, scheduling, and rescheduling its plans to put a large permanent station in orbit around Earth, the United States is finally moving ahead firmly with a whittled-down, but still impressive, space laboratory.

What \$15 billion will buy

In current dollars, U.S. funding will be about \$15 billion. That will buy the station's main structure, solar ar-

Continued

rays, and support hardware. It will also buy four large nodes, each with a large interior volume and six ports for connecting living quarters, laboratories, and other modules. Two nodes will sprout viewing cupolas outfitted with controls and data screens to allow astronauts unobstructed vision as they operate external systems or guide a shuttle into its berth.

Finally, the price tag includes a mixed set of modules to be attached to the nodes—air-lock modules for astronauts entering or leaving the station, twin docking tunnels for the shuttle, a medium-sized logistics module containing much of the station's operating systems, and two large units—a habitation module and a laboratory module—for living and working.

Three more large modules, a laboratory provided by Europe and laboratory and logistics modules from Japan, will be added during the first phase of construction. And a pair of remote manipulator arms, similar to the arm now carried by the American space shuttle and critical to piecing together the station and guiding the shuttle to its berth, will be provided by Canada. Total cost of the operational station, including both U.S. and international contributions, is expected to exceed \$20 billion.

The station was originally planned for full-time occupation by scientists and astronauts in 1992. If NASA sticks to its current schedule—a timetable that will be affected more by future budgets than by technical obstacles—the first space-station elements now will be packed into a shuttle payload bay and vaulted into orbit in early 1995. A total of 20 shuttle flights running through 1997 will bring the first phase of space-station construction to an end. The station will then be ready for eight full-time residents.

Private space facilities

The one or two unmanned space factories now planned complete the space-station system. If current plans aren't derailed in Congress, the privately owned U.S. Industrial Space Facility—or something similar called the Commercially Developed Space Facility (CDSF)—will be carried

into orbit in 1993 or '94. But as this article goes to press, its fate is a major question mark.

The Europeans are more certain. They expect to launch their own man-tended free-flyer facility to join the space-station armada in late 1996 or early 1997.

Former astronaut Joseph Allen calls the ISF a "toolshed." Pioneer space designer Maxime Faget calls it "a pathfinder for the space station." NASA isn't sure, but is caught in the middle of an argument over its worth.

"It would carry experimental racks identical to the station," said Faget, now chief executive officer of Space Industries in Houston, which designed and may orbit the little lab. Faget knows how to make things work in space. He's a pioneer whose designs for NASA strongly influenced every manned space program from Mercury to the shuttle.

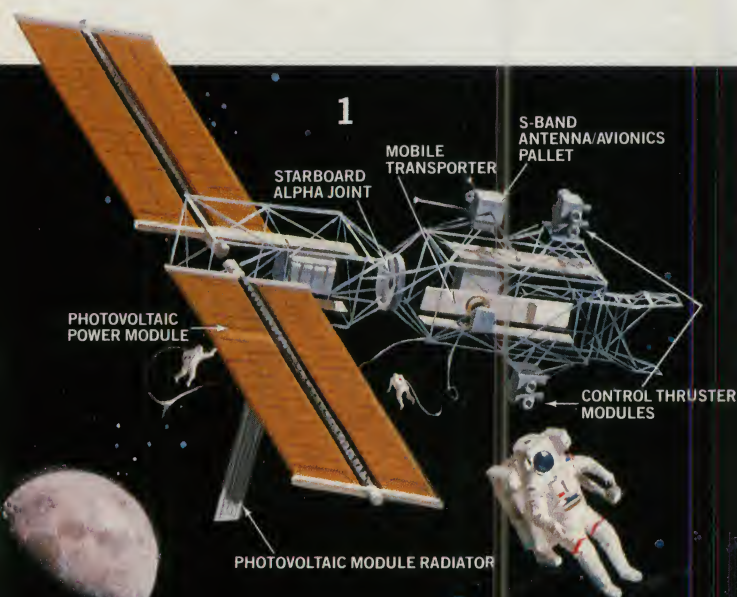
Faget began pushing the ISF concept after retiring from NASA in 1981. He was later joined by Allen, now president of Space Industries, and others who saw a niche in space for private industry.

On paper (most of the design and engineering is completed and the craft is ready to be built) the ISF is a \$1-billion pressurized tube with solar-panel wings, sort of an unmanned mini-laboratory. With a 14½-foot diameter and 2,500 cubic feet of internal volume, it could be carried into orbit by a single space shuttle, already filled with self-contained space experiments and autonomous systems for materials processing.

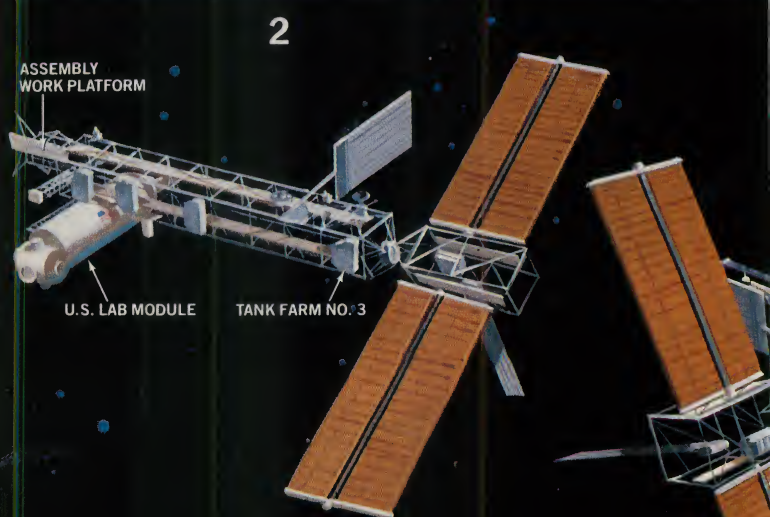
After leaving the shuttle bay, a pair of 100-foot solar arrays, providing up to 10.8 kilowatts of power, would deploy and the ISF's automated equipment would begin to work. The lab's interior would be pressurized but unmanned. Once every four to six months, it would be docked to a visiting shuttle. Astronaut crews would spend a day or two retrieving and replacing equipment, then leave the ISF to its lonely autonomy.

In concept, the facility has the same relationship to the space station that a pickup truck has to an 18-wheeler. But its future is now tied to the bigger program.

Faget foresaw that a privately owned laboratory would



Assembly plan calls for astronauts to leave a stable, fully powered section of the space station in orbit after the first mission (1). Truss elements go together to make three bays to which electronics packages, fuel-storage tanks, solar panels, and a mobile transporter—which moves along the truss like a trolley car and will eventually carry a robot arm—are attached. A pivot joint allows the solar panels to turn for maximum exposure to the sun. A large thermal radi-



tor bleeds heat from the solar module.

After only four assembly missions, the U.S. space station has grown to about half of its final size (2). The pressurized laboratory module allows "man-tended capability" with astronauts working inside part-time. The device protruding from the lab module is a shuttle docking adapter and tunnel. Control gyros maintain the station's attitude in space.

The station can be permanently occupied by four or more

be used by fee-paying companies or university science departments for micro-gravity experiments and perhaps even small-scale production of pharmaceuticals or other materials. But private customers have been slow to sign up. In early 1988 President Reagan told NASA to take out a \$700-million lease on much of the ISF and to begin using it in space in 1993, several years before the space station would be ready. NASA balked, then agreed on the condition that bids for building the little lab—now to be called the Commercially Developed Space Facility—be open to all. At that point only Faget's Space Industries team, which included Boeing and General Electric, seemed likely to bid.

Before NASA could follow through, Congress tied up the Industrial Space Facility by ordering its lease costs subtracted from space-station funds. Months of anguished and futile negotiation followed. In the end no real decision was made. With Congressional blessing, NASA ordered two more studies on the ISF and its usefulness. These reports will not be delivered until the middle of this year at the earliest.

If the Industrial Space Facility or Commercially Developed Space Facility is ever built, it will ultimately be moved into a trailing orbit behind the space station—close enough to be visited by shuttle crews, but far enough away to avoid contamination.

"Racks could be substituted back and forth between the space station and the ISF, so there's a strong incentive to use both," Faget said. "But the two are not the same."

Technology hurdles

With the ISF argument pushed to one side, NASA and aerospace-industry engineers face a few key technology hurdles before they can build the big station. One of them is critical. "We'll have a crew of eight with shuttle resupply missions every ninety days or so," said William R. Humphries, chief of the Life Support Branch at the Marshall Space Flight Center. "But the shuttle has a limited payload, so we're closing all the loops on the station." That means recycling water and oxygen, using new technologies never tried in space. "All the carbon dioxide will be

captured and cleaned, with oxygen returned to the cabin and carbon thrown away. Water will be cleaned and recycled in separate systems for potable and hygiene water."

The latter would be used in the station's clothes- and dishwashers, for showers, shaving, and other non-consumption activities. Even urine will be collected, cleansed, and put into the hygiene water system.

Water use totals 50 to 55 pounds per day for each crew member, Humphries said. "To replace it all would require five or six shuttle flights a year, just for water alone."

Reclaiming water

Instead, NASA and numbers of contractors are developing systems to reclaim, purify, and reuse every drop of water and every molecule of oxygen. Competing technologies will be evaluated and the best selected for full-scale development beginning next year, Humphries said. Even the methane gas generated by solid wastes might be useful as a fuel for the small rockets that help keep the station in orbit.

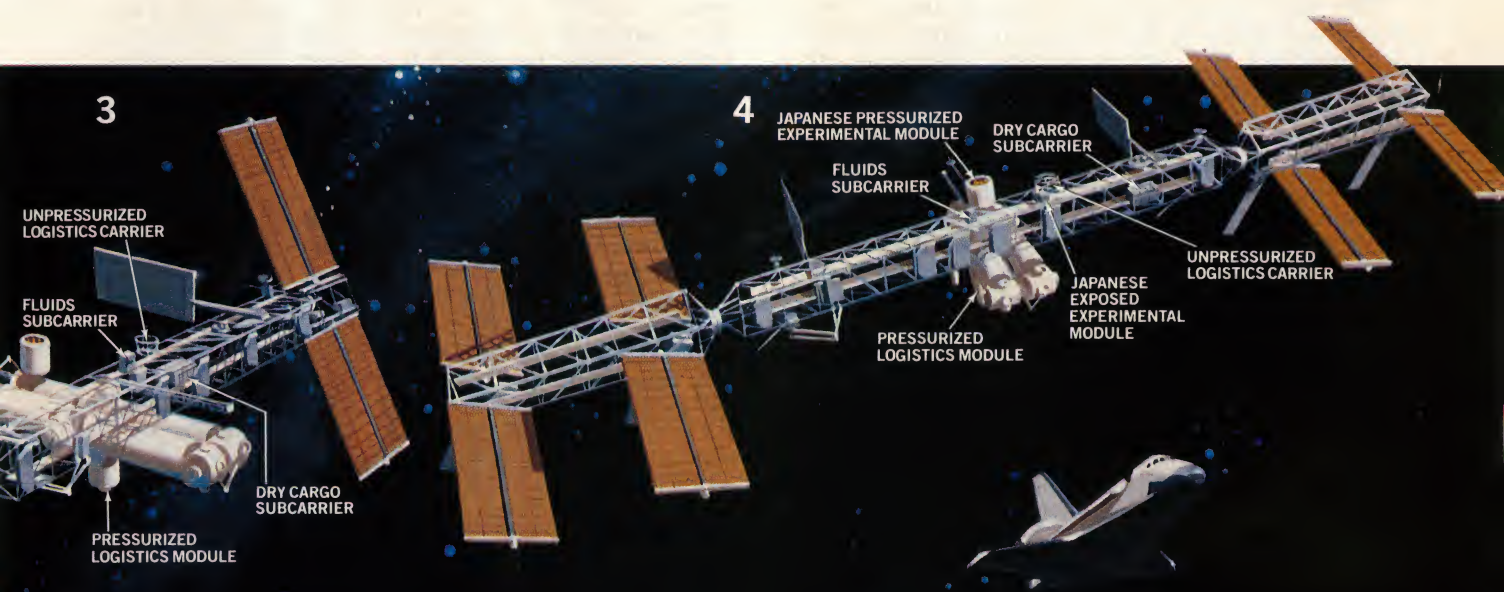
Initial results all look good, Humphries told me. "If this works out, there will be no water or oxygen resupply needed for the crew, and only occasionally for some experiments."

Other parts of the space station use existing technologies. Still, it will take 20 complex shuttle missions to get everything into space and assembled. When it's complete, the station will have a pod of pressurized modules slung under a long truss with solar panels at each end and a variety of other equipment attached above, below, and inside the truss.

"The first two flights will be the most difficult," said Daniel H. Herman, the program's chief engineer at NASA headquarters. "The truss has to be put together and the large solar arrays deployed. Once that's done, you have a completely functioning space structure, and you can relax."

In NASA's latest plan, astronauts on those flights will put together half of an orbiting erector set by assembling the first 60 meters of a massive truss. They'll also attach the first solar panels, electronics modules, attitude-control

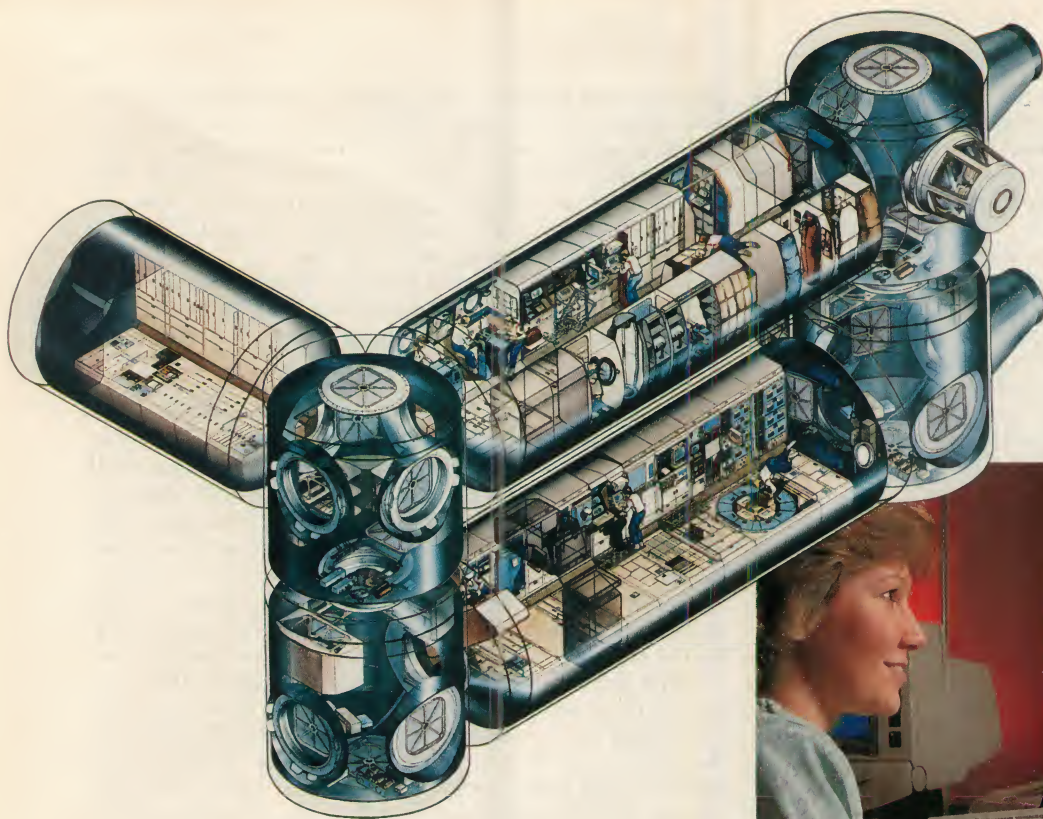
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people after the thirteenth assembly mission, which adds a large pressurized supply room (the logistics module) and several external supply carriers and pallets (3). In addition to extending the truss to its full 120-meter length, astronauts have installed additional solar panels, radiators, tank farms, and most major electronics and communications packages on flights 5 through 12. The U.S. habitation module is delivered and connected on the ninth mission, fol-

lowed by additional pressurized nodes and a cupola on missions 10 and 11. On some missions, most of the work is indoors as astronauts outfit modules with racks of scientific gear and equipment for day-to-day life in space.

After 20 shuttle flights, finally ready for its eight full-time residents, the U.S. space station has Japanese laboratories connected to the main living and working quarters, along with additional supply-room module (4).



Key modules for the space station (left) include habitation, with astronauts shown in rest and work areas (top center); laboratory (below habitation module); logistics, used for storage and transport of equipment and supplies (far left); and nodes for interconnections. A viewing cupola appears at far right in this Boeing concept.

Computer-aided design (see below) is used at the Marshall Space Flight Center for module planning.



thrusters, antennas, and other systems. The truss's open network of tubes will have a five-meter cross section and be loaded with equipment.

Putting it together will challenge the stamina and dexterity of astronauts assigned to the task. But both NASA engineers and experts at McDonnell Douglas Space Systems Co. in Huntington Beach, Calif., say that the job is within current technology. In late 1937 the company won the contract to design and build the truss and its support hardware.

"The truss will be carried up in the shuttle as a rack of poles," said George V. Butler, executive director of McDonnell Douglas's space station division. "Each pole will be labeled in sequence, and the astronauts will just put them together."

That scheme, company engineers decided, produces a truss that is stronger and more versatile than an erectable unit that would be launched in a folded configuration, then be extended or deployed in orbit. With the McDonnell Douglas system, only four separate components are needed—a five-meter pole for vertical and horizontal members, a 7.07-meter pole for diagonals, a small screw-in joist, and a ball joint that connects everything together.

Construction hardware

I looked at a full-scale mock-up of a truss section in Huntington Beach and marveled at its simplicity. "This is just one of three or four possibilities," Butler cautioned. "These are aluminum poles with an aluminum ball joint. But we're also looking at carbon-fiber poles and several other joint designs."

The final decision, he told me, will be made this year. The mock-up design looked good to me. The melon-sized ball joints were solid aluminum, each with 24 threaded holes drilled in precise "orbits" around its circumference. To build a truss, an astronaut would first screw an aluminum joist—a thick rod about five inches long with one end flanged and the other end a bolt—into one of the holes. A notched structural pole then would fit into the joist flange. Finally, the astronaut would pull down a locking sleeve prefitted over the end of the pole and with a quick twist

secure it tightly to the joist. After that, construction is simply a matter of extending the structure by adding more joints and joists, then attaching primary or diagonal poles.

At the busiest corners, eight poles—four primary and four diagonal—would be attached to a single joint. That leaves 16 more threaded holes for attaching other equipment including support structures that eventually will carry the pressurized modules, solar arrays, external space-station systems, and scientific hardware. Every hole won't be used, so the design is capable of growth and modification during the station's planned 30-year lifetime.

"It's a Tinkertoy setup," Butler told me. "It's a good engineering challenge, but not a big technical challenge."

On the first assembly mission in 1995, astronauts will plug together about 10 meters of truss, then install a pivot assembly about five meters wide. Beyond that point, they'll build another 15 meters of truss and install and deploy a pair of solar arrays. When unfurled, each array will stretch about 29 meters out from the truss. They'll produce peak power of about 18.75 kilowatts. The pivot, Butler explained, will allow the panels to track the sun while everything inboard of the pivot remains stable.

The first construction mission still won't be done. With the truss built, astronauts will return to the shuttle's payload bay and retrieve additional items. They'll install a telerobotic servicer platform that will eventually carry the robotic arm and move back and forth along the truss like a trolley car on rails. They'll also install the first of four tank farms for attitude-control fuel and other liquids, several avionics packages, a thermal radiator, and utility lines.

In space-station terms, utilities include fuel lines from

tank farms to attitude-control rockets, water lines, main power lines bringing electricity from the solar arrays to distribution points, and a variety of data and communication lines.

"Our biggest innovation is how the astronauts will install the utilities," Butler said. "Once you have all this real estate out there, there was a real question about that. We solved it by putting all the utility lines on a single big reel."

Butler pointed to a reel nearly 15 feet in diameter—the size was chosen to fit snugly in the shuttle payload bay—sitting at one end of the truss mock-up. I saw a row of linked trays containing the complete set of utility lines stretching out from the reel and ready to be fastened on the inside of the truss. At regular intervals, the trays included distribution points with plugs, valves, and outlets where utilities could be tapped and fed into space-station systems.

"It's not difficult to deploy," Butler said. "It will be power driven, and as the astronauts assemble the truss, they'll just pay out the utilities off the reel."

"We've had astronauts deploying utilities in the tank [an underwater facility where zero gravity can be simulated], and they say that it will be even easier in space where there's no drag from the water."

With the basic scenario in hand, McDonnell Douglas and NASA will work out the fine detail of space construction in the next few years. "The problem isn't only how you put it together," Butler explained to me, "but how you stack it in the shuttle and how you balance it and provide a stable platform in space once you get up there."

Actual construction on the first mission could take as little as 22 man-hours outside the shuttle, Herman told me. Astronauts on the the second assembly mission in mid-1995 will add about 30 meters of truss and install more electronics and support hardware. When they return to Earth after about 31 hours of space construction, the station's truss will be half finished.

Two missions later, just after Halloween in 1995, the station will finally be fit for temporary human habitation. To see the pieces that will begin turning it into a true space station I went to the Marshall Space Flight Center, where full-scale mock-ups of the main modules and the connecting nodes are being used daily to refine and complete the station's interior design. The flight modules will be built by The Boeing Co. in a nearby plant.

My immediate reaction to the mock-ups: "Those things are huge!" At 44 feet long and 14 feet in diameter, the habitation and laboratory modules are each the size of a railway car. The pressurized nodes that will connect the modules are about the same diameter, but only 17 feet 7 inches long. The first node and a shuttle docking tunnel will be attached to the truss on mission three. Then comes the lab module.

Working in micro-gravity

As big as they are, module size suffers from the normal Earth-gravity mind set. In the micro-gravity of space, where floors, walls, and ceilings can all be used with equal ease, the usable space inside the modules is much larger.

I stood first in the laboratory module and took a few mo-

ments to let my mind, if not my body, adjust to weightlessness. Engineers designing the modules' interiors face the same problem. The people who will live three to six months in the station will have it easier.

The railway-car analogy, I realized, was apt. The module has a long center aisle, 84 inches wide, surrounded on all sides by cabinets, cupboards, doors and drawers, scientific stations, recessed workbenches, and control panels. Four long rows of diffused lights—one at each edge of "floor" and "ceiling"—stretch down the aisle, giving the lab a bright but not glaring interior.

To help the crew maintain some sense of up and down, the major lab hardware is installed on the walls and the "floor" is a darker color than the "ceiling." Standardization is a key to both building and operating the station. Everything inside any of the modules comes prefitted in a standard rack, 42 inches wide, with its shape molded to fit snugly against the module's curved outer walls and adjacent racks.

Exactly what will be installed in the laboratory—NASA calls it "stuffing"—won't be decided until later this year. But the final installation will differ from the mock-up only in detail. "It will be a multi-discipline lab," said Walter V. Wood, NASA's project manager for the lab. "The physical sciences part of the lab will deal primarily with the micro-gravity environment and materials processing."

As I walked through the lab, I saw racks containing high-temperature furnaces, hooded enclosures, and glove boxes where scientists will not only create new materials, but analyze them on the spot. "They won't have to

wait for materials to be brought to Earth," Wood said. "They'll be able to process materials, analyze and characterize them, then rerun experiments as needed. That's a capability we've never had before."

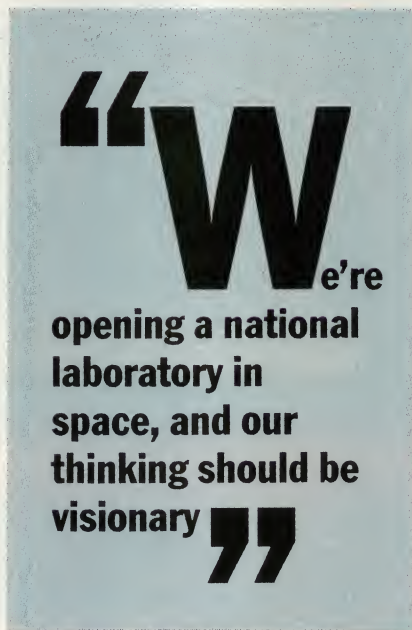
Looking down, I suddenly realized that I was standing on a bathroom. About the size of a cramped airline restroom, its location in the floor seemed perfectly logical in zero-g terms. The toilet was halfway up one wall. Next to it was the shower, not much different from the compact units found in motor homes. This one would be used both for emergency wash downs in the event of a chemical spill and for routine hygiene. A second shower and toilet are in the adjacent habitation module.

The floor also holds racks of environmental-control hardware, waste-management systems, and other systems needed to keep the station operating. Most of the science hardware will come in racks 74½ inches high.

In the ceiling, several compartments were marked "safe haven." Those would contain emergency oxygen, water, and rations needed to keep the crew alive in an emergency. Every module, a NASA guide told me, will have safe-haven storage areas.

Moving through the lab reminded me of being in an electronics store, with the aisle flanked by floor-to-ceiling display cases. In sharp contrast, the attached node flooded me with a feeling of spacious freedom. Though smaller overall than the main modules, the nodes are open and voluminous. Only a few racks hang from the bulkheads, which are purposely kept free because of the six docking ports each accommodates.

[Continued on page 141]





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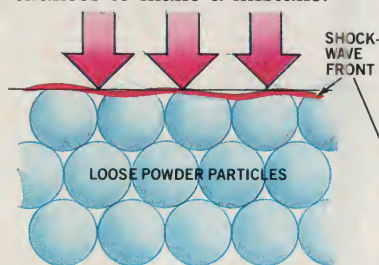
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BUCKLE UP FOR SAFETY.

By **STEVEN ASHLEY**
Illustrations by Jana Brenning

With the casual air of a homeowner who is filling his lawn spreader with grass seed, Tom Gould hefts a brown paper sack to the top of an upright section of eight-inch plastic pipe and starts to pour. BB-size pellets flow into the white cylinder until they cover a short metal pipe that's standing at the bottom of the enclosure. After placing the bag on the ground, Gould reaches down to spread the white granules around the interior. From his placid expression, you'd never know that he's sticking his hand into a 20-pound pile of high explosives.

"That stuff looks like fertilizer," I remark as the explosives technician checks over the apparatus. "It is," Gould replies, absently stroking his beard. "It's pelletized ammonium nitrate, a fertilizer, mixed with fuel oil—ANFO, for short," he notes in the soft measured tones that seem to characterize the speech of many staff members at the New Mexico Institute for Mining and Technology's Center for Explosives Technology Research (CETR). When I make this observation, Gould smiles slowly and then says, "That may well be so. In a business like this, you *have* to think things out beforehand; you just don't get many chances to make a mistake."



At CETR the business is bombs, blasts, bangs, and booms. The Socorro, N.M., campus, which extends over a barren range of high desert mountains suited for testing explosives, is just up the Rio Grande from the Trinity site—where the first atomic weapon was detonated. In 1983 the State of New Mexico, provided money for CETR's establishment. The Department of Defense, the National Science Foundation, Sandia and Los Alamos National Laboratories, and other governmental and industrial organizations now fund explosives research projects there.

Explosive metallurgy

For years explosives have been used in metal manufacturing. In one application they bond hard-to-weld metals to one another. For instance, when silver was removed from U.S. coins sev-

eral years ago, much of the so-called "sandwich metal" that replaced it was formed by using explosive sheets to slam metal slabs together and bond them.

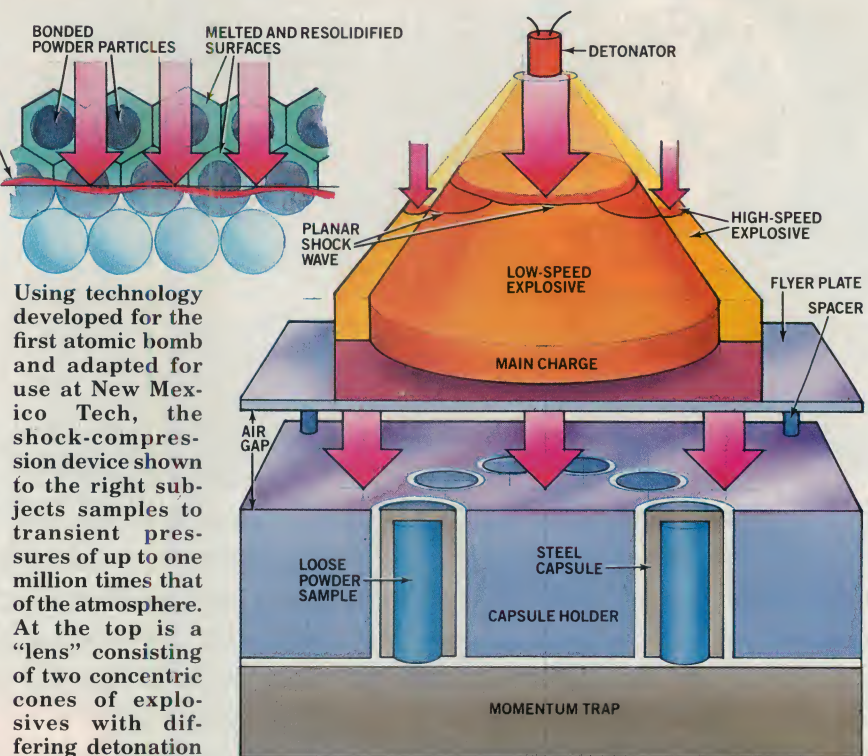
Interestingly, several artists working at New Mexico Tech have adapted similar techniques to create art. This "detonography" technique involves a

single sheet of metal, which is projected at supersonic speeds against a sculptured plaster mandrel by the firing of an explosive sheet. The design cast into the mandrel transfers to the metal sheet, yielding a handsome bas relief.

Lately, CETR researchers have been using explosives a little differently—to *make*, rather than bond or deform,

Most explosives are used to destroy things. But they can also create them. Researchers at New Mexico Tech are tailoring explosives to produce shock-wave "hammers" that can instantly forge super-hard metal and ceramic powders into ultra-high-performance solids.

DYNAMITE METALS



Using technology developed for the first atomic bomb and adapted for use at New Mexico Tech, the shock-compression device shown to the right subjects samples to transient pressures of up to one million times that of the atmosphere. At the top is a "lens" consisting of two concentric cones of explosives with differing detonation speeds. When detonated at the apex, their explosions progress at different rates, combining to produce a planar shock-wave front. This hammerlike wave drives the flyer plate down against the powder-sample cylinders at a speed of a mile per second and compacts the contents. The diagram at top left depicts the flat shock wave as it compresses the powder particles with force sufficient to melt their outer surfaces.

metals and ceramics themselves. By hitting powders with explosive shock waves that work like giant instantaneous mechanical presses, the particles can be fused into solids that are difficult to make otherwise.

"It turns out that certain high-performance materials such as hard ceramics and what are called rapidly

solidified metals cannot be consolidated from powders by other means," explains Naresh Thadhani, an assistant research professor at New Mexico Tech. "Ceramics are good at resisting compression and heat," he says. "And rapidly solidified alloys, produced by instantly 'freezing' small drops of the molten metal into tiny hard particles,

will separate into their elemental constituents if they're heated too long. But both types of materials can be consolidated into bulk forms by explosive compaction. When the particles are forced together under tremendous pressure, the surfaces melt, then solidify quickly, bonding them together."

Continued



The cylindrical shock-compression apparatus shown above surrounds the powder sample with explosive pellets. Upon detonation, the explosives cause the sample material to implode, compacting the powder granules into a solid.

Thadhani and I are now standing inside a concrete bunker that's buried beneath the clearing where Gould is finishing assembling the experimental charge. CETR staffers call this test site Big Eagle. The low-lighted blast shelter is filled with conduits, detonation triggers, timing devices, data recorders, and computers. In addition, it has a periscope and two ultra-high-speed cameras to film the experiments.

"Under shock compression," Thadhani continues, "interesting chemical reactions can occur. For instance, normally incompatible metals such as titanium and aluminum react under explosive shock to form titanium aluminide, an extremely lightweight, strong, and heat-resistant intermetallic alloy that's being considered for use in the skins of future hypersonic airplanes. In fact, that's what we're making in today's shot."

Amidst Thadhani's short discourse, Marc Meyers, CETR's associate director, moves out of the bright desert sunshine, past the heavy steel-plate door, and into the shady bunker. "Of course, that's not all we're fabricating with explosives," Meyers adds as he lounges against a concrete-block wall. "Other materials include nickel-base superalloys for jet engines and aluminum-lithium alloys—light, stiff airframe materials. The list goes on: super-tough diamond and cubic boron nitride cutting tools, gallium arsenide semiconductors, ultra-hard boron carbide and titanium diboride ceramic plates for tank armor, even the new high-temperature superconductors. With sufficient understanding of the process, we think that it's possible to scale the techniques up for economical industrial use."

Not just a big boom

"All this work comes from increased understanding of explosions," Meyers says. "When you look at a big explosion, you see a big boom in which lots of energy is released in a matter of micro- or nanoseconds. That's fine if you're just blowing something up. But if you want a *controlled* explosion, you need to see what's happening in there. With new diagnostic tools from the fields of chemistry and fluid mechanics, we're finding a logical, ordered sequence of events that we can describe quantitatively. Once we understand what's going on in an explosion, we can try to use this energy for our own purposes."

By now Gould, two other technicians, and Jim Kough, the graduate student whose experiment we're going to witness, have entered the underground enclosure to set up the equipment for the shot. The three of us decide to survey

the test site above. The test apparatus sits in a clearing at the base of a small valley. Piles of splintered wood, twisted rusty metal, and other debris dot the dusty plateau.

Thadhani kneels down to describe the apparatus: "Basically, we have the loose metal powder inside a metal cylinder that's surrounded by the explosive ANFO. All this is contained in the plastic pipe. On the side here there are sensors that report the progress of the shock wave to the computer." He points at wires leading to a cable that snakes across the ground to a hole where it dives into the bunker's roof. "When Tom gets back up here, he'll install the detonator and we'll be ready to go."

Zero hour

Ten minutes later the stone-strewn valley is still. Nothing moves, not even a stray dust devil. Barely visible among the dun-colored rock slides, cacti, and creosote bushes, the bunker crouches

“Once we understand what’s going on in an explosion, we can try to use this energy for our own purposes”

below the relentless sun. Save for Kough and me, everyone is inside. From our perch among some large boulders several hundred feet down the dirt access road, my telephoto lens can just make out the white cylinder standing alone in the clearing that roofs the bunker.

Off to the right a siren sounds for a couple of seconds as a red light flashes. The horn's echoes are just fading into the surrounding hills when a flame erupts momentarily from the white cylinder. Instantly the cylinder disappears and is covered by a roiling cloud of gray dust and smoke. Then, following a short pause, the loud rumble of the blast arrives. The cloud continues to rise until it fills the valley.

As the dust settles, the massive door to the bomb shelter opens and several figures emerge. By the time we reach

ground zero, the others are hunkered down near where the white cylinder once sat. Now there's a lunarlike crater dug out of the gray dust.

After picking through the dirt for a few moments with long tongs, Kough lifts up a five-inch-long blackened metal bar. It still smokes a bit from the blast.

Cracking conundrum

Back in a classroom on the New Mexico Tech campus, a small well-watered enclave of green grass, trees, and low school buildings sitting amid the dry desert, Meyers and Thadhani show me a series of explosively compacted samples.

"You can see that many of these bars have cracks in them," Meyers says. "It's our biggest problem. The cracks arise when the initial compressive shock waves reach outer surfaces. The surfaces reflect back tensile stress waves that crack the now-solid metal."

"That's why we use ANFO for the explosive," the researcher explains. "ANFO has about half the detonation velocity of TNT, which means it produces a gentler shock. We also try to trip the wave with the appropriate geometry. But it's not enough."

"We're working on two techniques that we think will help us solve this post-shock cracking phenomenon," he continues. "The first method is to pre-heat the powder just enough to make it a bit more ductile, which reduces the chance of cracking. The other way is to mix elemental powders, such as straight titanium and aluminum, with the rapidly solidified intermetallic particles. The shock causes the elements to react chemically, which produces enough heat to increase ductility and thus minimize cracking."

Thadhani pads out of the room and returns holding a lab thermos that's giving off what looks like steam. "Now for the *pièce de résistance*," he says with a grin. He pours a steamy liquid into a styrofoam container. "Liquid nitrogen." Thadhani places a small black disc into the container. "Superconducting ceramic," he says imitating a magician's spiel. "We compacted the powder in one step with explosives." Thadhani picks up the disc with forceps and places it above a small magnet on the table. Like magic, the disc hangs in the air.

"It shows that we did make superconducting ceramic," Meyers says. "One concept has us digging a long ditch, pouring the ceramic precursors into it, and then explosives. Afterward you detonate the explosives, and the shock forms superconducting cable *in situ* in the ground." It's a nice idea.



PHOTOS BY JOHN B. CARNETT

Say, Smokey: What's the car engine of the future?

It was 25 years ago this month that veteran race mechanic and engine maestro Smokey Yunick began offering the readers of *POPULAR SCIENCE* advice on how to debug their ailing vehicles. To mark his silver anniversary, the editors asked the straight-talking Floridian how the automobile—past, present, and future—looks to him. He forecasts a blueprint for the compact, efficient engine of the year 2000, and reflects on automotive issues from computerization to air pollution.

Growing up on a farm in Neshaminy, Pa., Henry Yunick was fascinated with things mechanical. By the time he was about 13 years old he had cobbled together a makeshift tractor from an old Dodge car, the rear axle from a Ford Model T truck, and some other parts. He soon found work as a machinist and welder. A strong-running but oil-burning Indian motorcycle the young

Yunick piloted inspired a race-track announcer to give him the nickname "Smokey." It stuck.

At age 16 he joined the Army Air Corps and spent 4½ years flying bombers in World War II. On a cross-country flight he glimpsed Daytona Beach from the air and decided it was the place to live after the war.

Smokey made a name for himself in the late 1940s as a builder of winning

race cars, beginning with Hudson Hornets and moving on to put Chevrolets, Fords, and other makes into the winner's circle at the top stock-car ovals around the country. He earned a reputation as a wily rule bender who kept pre-race technical inspectors up all night scrutinizing mechanical details that usually met the letter, if not the spirit, of the regulations. He built a

Continued

number of cars for the Indianapolis 500, including an unorthodox "capsule car" in 1963 that placed the driver in a separate pod alongside the main body for reduced drag and better weight balance.

In addition to his racing activities, Smokey ran a car, truck, and diesel-equipment repair business in Daytona Beach known as "The Best Damn Garage in Town." He has also done a steady stream of contract engineering jobs, many of them involving engine development, for Detroit auto makers. Currently on the front burner is his "adiabatic" hot-vapor engine, which is designed to improve power and fuel efficiency by recycling heat that conventional engines throw away. An earlier phase of the project was featured on the cover of *POPULAR SCIENCE* in April 1983. Smokey began his long association with the magazine in March 1964, when his "Say, Smokey—" question-and-answer column first appeared.

The veteran builder of monster racing engines drives to work in a 1980 Ford Fiesta, which he likes because it's "simple, fuel-efficient, and it works. That's all I need." Long known as a gadfly with harsh words for the ways of big car companies, he also worries about environmental damage caused by fossil fuels. With Deputy Dog, his pony-sized Great Dane, sprawled feet-up across the floor, Smokey recently settled down in his grimy book-lined office for a marathon conversation with *Associate Editor* Stuart F. Brown, who has deleted the expletives.

SMOKEY ON

... the efficient engine of the year 2000

This is my design for a three-cylinder 2.5-liter engine that will get you from point A to point B using only two-thirds of the fuel the same-size engine uses today. It does this by recycling some of the heat energy that's normally thrown away by the cooling and exhaust systems, and using it to improve combustion efficiency. Depending on how it's tuned, the motor could develop from 200 to 300 horsepower, while getting from 50 to 70 mpg. It will weigh only about 150 pounds and be able to meet all planned emissions standards. There's no reason this engine couldn't be in mass production in the year 2000. All of the technology is available now.

The engine sketched here represents the fourth generation of "hot-vapor" or adiabatic designs I've developed over the past 35 years. I expect to catch a lot of flak about the way I put the heat back in the front end of the motor, and I wouldn't be surprised to see some-

body else figure out a better way to do it. But the basic principle isn't going to change: We've got to quit running away from heat because, man, that's backwards. We pay to make the heat, so why not use it?

A standard cooling system pulls one-third of the heat out of the engine and transfers it to the air, where it doesn't turn any wheels. Another third blows out the exhaust pipe. Our best engines today are only around 30 percent efficient. By throwing away less heat energy, this one gets about 35 percent efficiency.

First, it's a two-cycle power plant. Why would we want to make two revolutions of the crankshaft to get one power stroke if there's any way to avoid it? I use a pressurized lubrication system that lets the engine run on straight gasoline—not like a chain saw, where you mix oil with gas. This helps it to meet exhaust-emission rules.

In a two-cycle you essentially make twice as much power by firing twice as often as the same-size four-cycle engine. My engine is supercharged so that adequate fuel-air mixture can be loaded and exhaust unloaded in the short time available during one engine revolution. A Roots-type supercharger gives the intake air a push at cranking speed and at very low engine speeds. As engine speed picks up, the supercharger declutches and a modified turbocharger takes over. Incoming air runs through a bypass duct around the supercharger when it's shut off.

Fuel is added by a simple throttle-body fuel injector that sits on top of a double-walled preheating chamber. Hot coolant from the cooling system circulates between the chamber's walls, heating the fuel-air mixture to about 200 degrees F as it passes through.

Next the mixture enters the modified turbocharger—I like to call it a homogenizer—that has exhaust-heated double walls in its impeller section, the part that feeds the engine. As it's spun through the impeller at up to 200,000 rpm and hits the hot turbo housing, the fuel and air get thoroughly and evenly vaporized. The hot vapor is now heated to about 275 degrees F.

The intake manifold is also double-walled and heated by exhaust. On its way through the manifold, the vapor picks up some more heat and enters the engine at about 300 degrees F. This rapid three-stage heating and mixing process lets the mixture burn completely inside the engine without any knock or detonation—the uncontrolled combustion that can blow a hole right through a piston.

The fuel vapor produced by this system won't detonate until it reaches 400 degrees F. Fuel mixtures delivered by

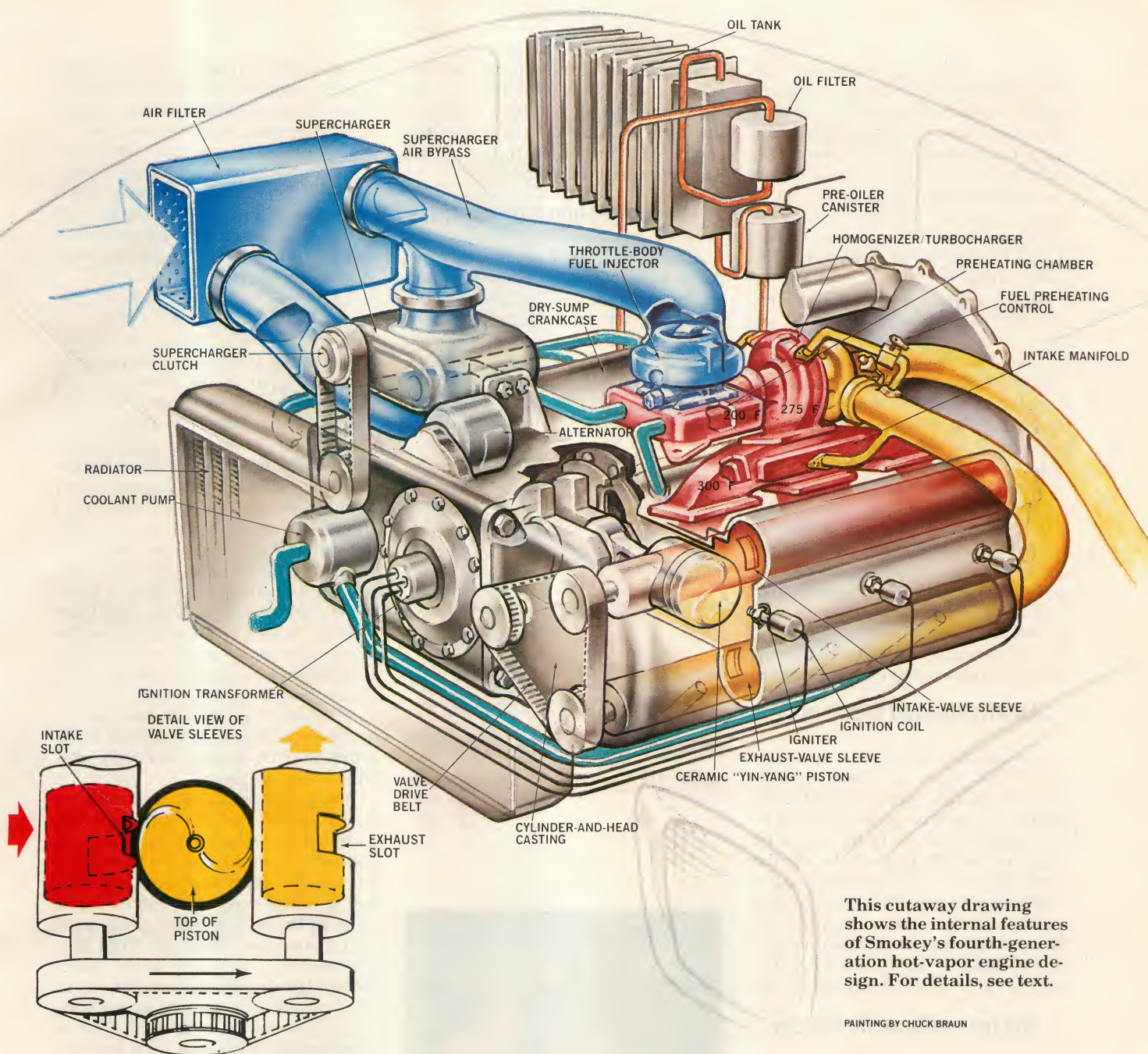


This is a 2.5-liter four cylinder GM "Iron Duke" engine converted to my first-phase hot-vapor design. It makes 250 hp at 5,200 rpm and 270 pound-feet of torque at 2,800 rpm. The motor meets 1988 emissions standards.

conventional carburetors and fuel injectors begin to detonate at only 235 degrees. I believe that's because they don't vaporize all the fuel, causing it to burn unevenly and incompletely. I'm sure I'll hear arguments on this.

Most two-cycles take in fuel and let out exhaust through port windows cut into the cylinder walls. This one's different. It breathes through rectangular slots in the roof of the combustion chamber. The fuel vapor is piped in and exhaust is channeled out through hollow rotating valve sleeves with cutouts that match up with the slots in the cylinder head. The valve sleeves are belt driven and turn inside close-fitting tubes, with a thin film of oil maintained between them. They create very little friction compared with four-cycle poppet valves, springs, and cams, and are simpler to manufacture.

This engine runs hotter than a conventional one, so it uses a high-temperature-rated synthetic lubricant, and several components are made from silicon-carbide ceramic material reinforced with fibers or metal "whiskers." The intake and exhaust valve sleeves and tubes, the pistons, the wrist pins, and the cylinder-liner sleeves are made this way. I've tested this stuff, and it's ready to be used for these kinds of hot-running parts. The piston crown and the combustion-chamber roof have mating "yin-yang" surfaces that cre-



This cutaway drawing shows the internal features of Smokey's fourth-generation hot-vapor engine design. For details, see text.

PAINTING BY CHUCK BRAUN

ate a spiral combustion pattern; this helps burn the fuel completely.

Who needs leaky head gaskets? That's why I've designed the head and cylinder block as a one-piece casting. It bolts onto a compact cast-aluminum crankcase. I use a racing-type dry-sump lubrication system that stores most of the engine's eight-quart oil supply in a finned external tank that cools the oil before it recirculates through the internal lubrication passages.

Dry-sump systems are dead reliable and avoid the horsepower loss and senseless heating caused by the crankshaft thrashing around in a bath of oil. They also make for a flat-bottomed engine that can sit several inches lower in the car for a better center of gravity. This lets the stylists design a body with a sloping, aerodynamic hood line.

On its way into the oil tank, the lubricant goes through a filter that cleanses *all* of the oil. Most oil filters today have a bypass valve that routes some of the lubricant around the filter when pressure is high or when the filter clogs. I say you should always filter all the oil. When the oil leaves the tank, it runs through a pre-oiler canister that retains $\frac{3}{4}$ quart of oil under pressure when the engine is shut off.

The next time you turn on the ignition key, a solenoid opens, charging the engine with oil before it starts. A pressure switch won't give the engine an ignition spark to run until it senses oil pressure in the system. This is an engine that just won't start unless it has plenty of clean oil at the proper pressure, and it's going to last a hell of a lot longer than what you see today.

An ignition transformer takes current from the battery and sends it to individual ignition coils at each cylinder. The coils feed high-amperage low-voltage current into igniters that look a lot like spark plugs. These igniters have an electrically charged cavity that reacts the fuel-air mixture in the cylinder when the piston has reached the optimum point for best thermal efficiency. This point is determined by temperature, pressure, engine speed, fuel quality, and igniter location.

This type of ignition system is simple because it requires no distributor or advance mechanism to trigger the spark. It helps efficiency by letting the engine run extremely *lean during deceleration and idling*.

The engine's coolant temperature is

Continued

about 300 degrees F, compared with about 220 degrees in most of today's engines. Engine temperature is kept more uniform by using a high-boiling-point coolant such as propylene glycol and routing it "backward" from the conventional flow direction to spread heat from the combustion chambers down through the engine block ["Cooler Heads For Hotter Engines," June '86].

What's a good way to make an engine last a long time? One good answer is to keep the piston speed reasonable. I don't think this engine would ever have to turn over 3,000 rpm. Remember, you're making twice the power of a four-stroke at any given engine speed, so you could cruise at 60 mph turning only about 1,200 rpm.

I already want to look beyond this engine—which is buildable right now—to the next generations of thermally efficient power plants, which could someday use as much as 80 percent of the energy contained in the fuel. I say better sooner than later. So let's get serious about developing the high-temperature materials and lubricants that will make these engines work.

... Americans and their cars

I consider the automobile an extension of the American's body—of my body. I couldn't function without a damn car, and most people couldn't either. And I'm not talking about for pleasure. I'm talking about the way our whole life is set up. I'm talking about everybody who works for someone else, or sells things, or has a business. For the majority of people, it's just not possible to consider operating without a car. That's the way the country works.

... the love affair with the car

From the 1930s until 1955 some good changes happened to cars: better brakes, better steering, better handling, a little more power, and better fuel mileage. The cars were pretty damned reliable and simple.

When you broke down, there was some farmer, truck driver, or gas station mechanic who could stop and put a Band-Aid on it, enough to get that sucker on to a more convenient location to fix it. You didn't have to call the wrecker very often.

During this period, anybody who had 10 years of education, and who could read and ask questions could maintain his own car. This was when people in the automotive business talked about "America's love affair with the car." It was pretty much true, and it happened because people could work on their own cars and save money.

It was a constant learning process. When a guy bought his first car, he didn't know too much about it. But by the time he was 40 years old and bought his third or fourth car, he had learned quite a bit about cars.

... the power and bigness craze

After 1955 Detroit got into a horsepower race, which translated into an engine-size race. Engines grew all the way up to 500 cubic inches.

The stylists went crazy and started hanging fins on cars that were huge, heavy, and aerodynamically horrible. Some of the cars looked like Buck Rog-

"I predict we will eventually get a simple car, and the first maker that does this will win all the marbles"



ers star ships and ballooned up to 5,000 pounds. Economy dropped to about 10 mpg. The cars made no sense whatsoever. They were way overpowered.

By the middle of the 1960s we started seeing muscle cars that were capable of going 160 mph with brake and suspension systems that were 30 years old in design and just plain poor. But at least those big, heavy cars were still pretty simple.

... today's cars

Some good things have happened to cars in recent years. New cars are much more comfortable, and ride, handle, and stop better. They don't require chassis lubrication, which most people neglected in the past. Anti-lock brakes are a big safety breakthrough. They ought to be mandatory on cars. But I think ABS can be accomplished without computers, like Lucas Girling in England has done [Jan. '84, Sept. '86].

I always consider how long it takes to get a problem fixed. If you need more than a fan belt or a radiator hose for your car, a repair job is going to take three days or longer today because the dealer hasn't got the parts. And you can't blame him for not stocking everything, because there are too many different parts that change every year. This is not progress.

When cars were simpler I could go to the local dealer and get everything I needed to fix your car the same day. Since then manufacturers have made cars more complicated, packing them full of unnecessary stuff. For example, what in the hell would anybody want with four-wheel steering? What does the average guy want with four-wheel drive? Has anybody thought about what it will cost when it comes time for a valve job on a 32-valve V8? As complicated "high-tech" cars begin to wear out and their owners start to find out how much it costs to fix them, a lot of people are going to lose interest in all this fancy stuff.

... computers in cars

In the future I think we will have fuel injection, but with a \$75 to \$100 stand-alone computer package that only controls the fuel system. The computer will be diagnosed by a simple \$100 tester that lights up green or red.

Electronics need an environment not normally found in cars—stable temperatures and atmosphere. They also require gentle handling. I hope that the only electronics in our cars will be in the fuel-injection system and the ignition advance. That's what they are good for. Anything else is just an unnecessary complication and an invi-

tation to maintenance headaches.

You can put the chief engineer of most car companies in one of his '89 cars, and if the engine quits running in the middle of nowhere, he's not even going to open the hood. He's going to start walking. Because he knows you need a lot of bulky diagnostic equipment to find the problem and fix it. That's the truth.

... cars of the near future

I predict that we will eventually get a simple car, and that the first manufacturer that does this will win all the marbles. Once that happens, all this high-tech stuff will disappear and there will be a race to get simple. Improved fuel and combustion systems will not need all of the emissions gadgets. The selling word will be: Our car is simple, our engine is simple.

Manufacturers have already started to sell simplicity. I saw a Buick TV ad recently where it shows the parts of a German car engine and a Buick engine all spread out. Then Buick claims how much simpler its engine is.

Did you ever wonder why everybody suddenly went truck crazy? Trucks are simpler than cars; they don't have all the same safety and emissions equipment. Now all that stuff is being mandated for trucks. Watch the sales drop.

... emissions controls

When the emissions rules first came along, the car makers all stuck their

heads in the sand like ostriches and hoped the government would eventually lose interest and stop pushing emissions. The manufacturers played around with catalytic converters, and air pumps, and exhaust-gas-recirculation valves, and all sorts of plumbing. Everything that they did was a quick short-term thing. The peak of the sorri-ness came in 1984. Those cars couldn't run right. There's no kind way to put it—they were junk.

What saved them was the computer chip. The whole computer thing was born of the need to pass emissions and improve mileage. It began about 15 years ago when a bunch of bright young electrical engineers who loved to play with their computers were coming to the top in Detroit—just at the time when their bosses had run out of ideas.

The new guys threw the carburetor away and put in fuel injectors that metered fuel into the engine in a miserly way. Emissions looked good that year, and mileage was higher. This was progress! Unfortunately, the cars didn't run too good.

The electrical geniuses knew computers, but they didn't know cars. Well, they've been in the learning process awhile now, and they're doing a lot better. They have figured out how to run engines lean and virtually shut them off on deceleration. The engineers found that by computer metering the fuel, they could get good idle and throttle response. They're finally making engines run right.

... energy and emissions strategy

Using less fuel is the only honest-to-God, bulletproof way to cut down on emissions. For years I've been saying that the government should limit car engine size to 2.5 liters. You can turbocharge it, supercharge it, or whatever the market will bear. The winner will be the car that best fits each individual job.

We can produce 300 hp with 2.5 liters, and nobody in the United States needs more than 300 hp in his automobile. Eventually, there's no reason we couldn't get by with 1.5 liters. I want to see a dead-serious mileage standard—like the CAFE (corporate average fuel economy) was supposed to be—that gets higher every year. Enforcement would be simple: If you don't meet it, you don't make cars this year. Right now, we should be at around 38 or 39 mpg—really tough mileage. There's no reason we couldn't up it by one mpg per year for the next 100 years.

The government was dead wrong to back off CAFE. This business of saying that if you mandate this mileage you're putting thousands of people out of work, that's garbage. The standard didn't just appear last week. Car companies had plenty of time to get ready.

... fuel

I don't see gasoline being replaced as the major fuel in the foreseeable fu-

[Continued on page 149]



This Chevrolet Chevelle (below) was the state of the art in stock-car racing in 1968. It has a 416-cubic-inch big-block engine that makes 625 hp on the dynamometer. The car was built to run in the Daytona 500 race that year, but the technical inspectors said there were 10 things wrong with it; I had two hours to correct them. Number one was to replace the frame. These are big V8 racing engines (left) I've built over the years. I restored all of this stuff and held an auction recently to get some of the clutter out of my shop.



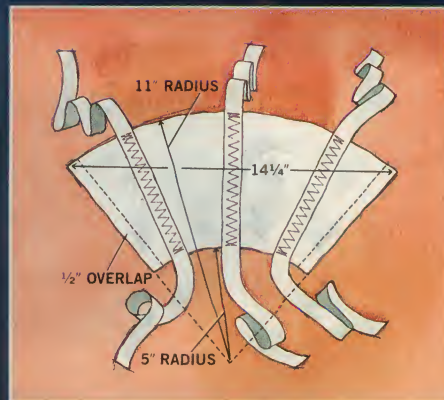
A dramatic illustration of a sailboat with a white hull and red accents, struggling against massive, dark blue waves under a stormy, dark sky with lightning. The boat is tilted, and white spray is visible around its base. A rope with several blue, cone-shaped floats extends from the foreground towards the boat.

Getting caught in a violent storm is a sailor's nightmare. A new sea anchor ups the odds for survival—and it's not hard to make one.

OCEAN GRABBER

By DONALD H. VAN LIEW

The cones are made from 1.5-ounce ripstop Dacron sailcloth, available from sail makers. Ribbons of $\frac{3}{4}$ -inch nylon tape 23 inches long are sewn to the material before the edge seams are joined. Cones are then spliced into the $\frac{3}{4}$ -inch braided line. A report describing the construction in detail is available from the National Technical Information Service, Springfield, Va. 22161. Ask for document #ADA188598; \$14.95.



A new weapon has been developed to aid ocean mariners against that age-old menace to small craft—killer storms. The simple new sea-anchor design works better than conventional models

... and almost anyone can make one.

The uncomplicated boat saver, which looks something like a parade of jellyfish in single file, is called a series drogue. It consists of 90 or more five-inch-diameter cones of sailcloth attached every 20 inches along a long length of line. A 30-pound weight fastened to the end of the line keeps the drogue from popping out of the water, no matter where the boat is in relation to a wave, a common problem with existing sea anchors.

The ocean-grabbing device was developed by U.S. Coast Guard researchers after tests showed that conventional sea anchors, which use a single large fabric cone, or "parachute," are subject to fatigue failure as they fill with water and then collapse under the strains generated by storm waves. Often these anchors are destroyed before the storm calms.

Another shortcoming of the single-cone design shows up in 20- to 30-foot breaking seas; there is a dangerous time lag before the conventional sea anchor catches the water and orients the boat to ride safely over or through a breaking wave. This delay can leave the boat turned sideways to the wave, causing it to capsize. It can also cause the bow to dig into the water as the wave overtakes the boat, making it pitchpole by flipping stern over bow. Not many sailors live to tell about this terrifying experience.

The string of little cones used in the series drogue ensures that at any time most of them are filled and grabbing hold of the water, so that the boat remains properly positioned for the next wave strike. (That proper position has been found to be "stern to" the oncoming waves; this keeps the boat running with the wind and waves, lessening the relative speed of the onrushing walls of water.)

The new anchor's steadier grip on the sea also ensures that the boat's fittings are under a more-constant load, which is less likely to destroy them. In fatigue testing, the anchor was subjected to 15,000 cycles—the equivalent of a giant hurricane—without a failure. It still looked new and unworn, with only the new-cloth stiffness gone from the cones.

The series-drogue design is in the public domain. That means that you can make it without paying royalties. The Coast Guard team that developed it hopes boaters will add this easily made and stored device to their boat's inventory of safety equipment... ready for use when it really gets rough out there. **P S**

Bizarre binding for the slopes

It was sunny, windless, and the snow at Vermont's Stratton Mountain was in prime condition. But I was *not* having fun. The problem: I was trying to keep up with ski instructor Stefan Schernthaner (a former racer) while wearing strange new boots and bindings made by an Italian company called Nava.

And I do mean strange.

Normal ski boots are rigid plastic affairs designed to translate motion that originates in your hips and knees down to your skis, which are shaped so that they will turn when you apply the inside edge to the snow. To get the ski in that position you must (while barreling downhill) shift your weight to one ski and dip that knee downward and inward. Do it right and around you go. It's called carving a turn, and turning is what skiing is all about.

The Nava ski boot, on the other hand, is relatively soft and heavily insulated, comfortable for both walking and skiing. So how do you get the ski up on edge? Enter the bizarre binding. Its most prominent feature is a long rigid control arm that attaches to the ski behind your heel and snakes up your calf nearly to the knee.



Frank Vener, president of Nava USA, explains: "The control arm is steel inside and very rigid. It attaches directly to the ski and comes up much higher than a standard boot. As soon as you move your leg the energy is transferred directly to the ski. So you get quicker, more powerful edging. And getting the ski up on edge is easier because you're working with a longer lever." Nava bindings are also safer, the company claims.

Good thing, I thought, feeling dangerously unstable as I plummeted down the slope. Fighting the equipment soon had me tired; I called a time out.

Schernthaner obliged and we doffed our skis for a break at Stratton's scruffy Sunbowl lodge. "Try to forget the equipment," he advised, "and keep your weight forward."

Back outside he launched into a full-scale ski lesson, and before long I had indeed forgotten about the gear. By quitting time I was skiing better—and faster—than I ever had.

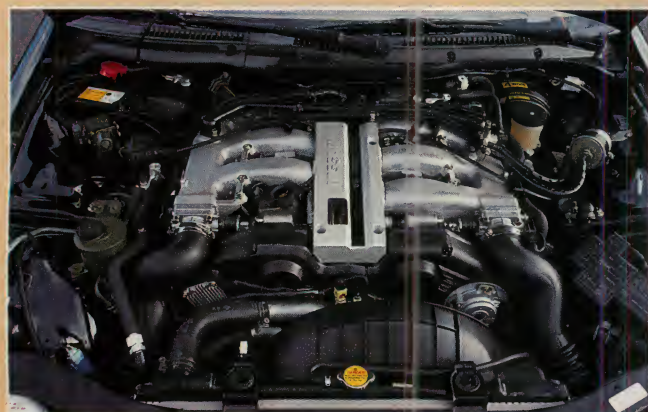
Would I have to buy pricey new equipment to ski this well again? I wondered as I returned the Nava gear. The answer turned out to be no; I've found that my improved technique carried over to my conventional gear.

Should I credit Schernthaner's excellent instruction, the Nava equipment, or some combination? I don't know. But the gear does seem to reinforce proper skiing while being pretty unforgiving of common errors.

Nava boots and bindings come in men's and women's sizes and in two models: the Cortina (\$595) and the Sansicario (\$495). Nava Leisure USA, 49 Riverside Ave., Westport, Conn. 06880.—V. Elaine Gilmore

The Nava ski boot has a waterproof fabric shell and a quick-lace inner boot formed mostly of foam for warmth, comfort, and easy forward flex. The binding is built around the control arm, which rests against the calf. Pistonlike, it moves to follow your leg movements fore and aft as you ski. When, in a fall, the binding releases the boot, the control arm folds down on the ski and serves as a brake to keep the ski from sliding away.

HOT NEW



The new Z-car's interior styling follows a capsule theme: The instrument panel flows smoothly into a high central console to split the driver and passenger into two discrete cockpits. Instrumentation takes the form of large, easy-to-read analog gauges with switchgear mounted on satellite panels near the three-spoke steering wheel. The three-liter 90-degree 24-valve V6 engine produces 222 hp in base form, and 300 hp with twin turbos and dual intercoolers.

By **DON SHERMAN**
Photos by Yoshifumi Ogawa

While Nissan didn't invent the affordable sports car, it certainly advanced the cause when it introduced the Datsun 240Z in 1970. An instant hit at \$3,600, this Japanese rendition of the Jaguar E-type rushed forth and multiplied. Unfortunately, the inevitable aging process took over; as it grew old, it got fat and lost its sports-car edge.

Believing that lightning can strike the same spot twice with the help of a well-engineered rod, Nissan created an all-new Z-car for the 1990s. On a recent trip to Japan I had an opportunity to see and drive the new 300ZX, which goes on sale in April.

All-new design

By starting with a clean sheet of paper and applying the latest technological breakthroughs in engine design, steering and suspension geometry, braking systems, and structural analysis, Nissan engineers created a 300ZX that should last through much of the next decade.

While the blueprint is familiar—a rear-drive two-seater powered by a three-liter V6 engine mounted up front—the



result is nothing like the past generation of Z-cars. The styling is fresh and interesting. Dimensional changes are all in the right direction: Height, length, and overhang have all been aggressively trimmed, while wheelbase, width, and track have all been increased. These changes give the new 300ZX a leaner stance and a more stable feel. Power is up substantially and there is only a 55-pound weight gain, so the power-to-weight ratio moves smartly in the right direction.

Whenever expensive high-technology solutions were deemed necessary, they were included without hesitation. For example, the headlamp system uses projector-type bulb-and-reflector light sources covered with flush-fitting glass lenses that blend in with the hood line.

The three-liter engine has been thoroughly revamped to hike the output from 165 to 222 horsepower at 6,400 rpm. The new under-the-hood hardware reads like an engine designer's wish list: twin cams, four-valve-per-cylinder heads, distributorless ignition, and variable intake timing. The engine-control computer regulates a

two-position hydraulically actuated intake-cam sprocket that at low engine speeds advances the intake valve timing to smooth idle, boost torque, and improve fuel economy. In addition, a 300-hp turbocharged engine that boasts *twin* turbochargers breathing through a pair of air-to-air intercoolers is slated for introduction in October.

The new five-link front suspension is all new. According to Takaaki Uno, Nissan's head of chassis design, "The breakthrough came with using an extra link that eliminates the need for any trade-off, because it allows both a stable vehicle attitude during cornering and good vehicle stability during braking."

The rear suspension is a variation of the four-link layout on the 240SX. To stop the car, huge disc brakes with vented rotors and four-piston aluminum calipers in the front work in concert with twin-piston rear calipers. ABS is standard equipment.

300ZX test drive

My test drives at Nissan's Tochigi proving grounds convinced me that the new 300ZX will rattle the opposition and enliven sports-car buyers. It was electrifying to drive and impressively fault-free, even in prototype form. I clicked off seven-second 0-to-60-mph times, and brought the car to a stop in 125 feet, as measured by the POPULAR SCIENCE fifth

wheel. I hit a top speed of 147 mph and cornered at a neck-bending 0.89 g. But, best of all, I enjoyed the new zest in the Z's handling manners that will surely convince buyers this two-seater is worth a few sacrifices—like its estimated \$25,000 price tag. **P.S.**





You can turn your portable router into a super-versatile overarm pin router by building this simple and inexpensive mount.

By R. J. DeCRISTOFORO

Sometimes I think the perfect woodworking tool would be an extra hand or two. Trying to hang onto my work, make accurate cuts, as well as maneuver a hand-held router is one scenario that comes to mind. Accuracy is important because I use my router for everything from shaping woodworking joints to fashioning decorative silhouettes. My solution: I built a simple mount for my hand-held router and turned it into a versatile overarm pin router.

There are many accessories for portable routers, but most add (or simplify) only one specific operation. The overarm pin router is able to handle any operation normally done by hand-holding the router—and more—but without the many jigs, guides, and fixtures that are otherwise required. It adds convenience, allowing faster

Hands-off

setup and increased accuracy because you don't have to hold and control the tool at the same time.

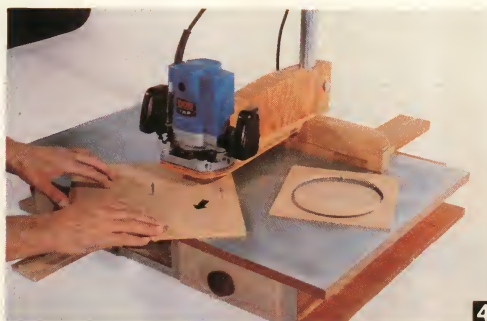
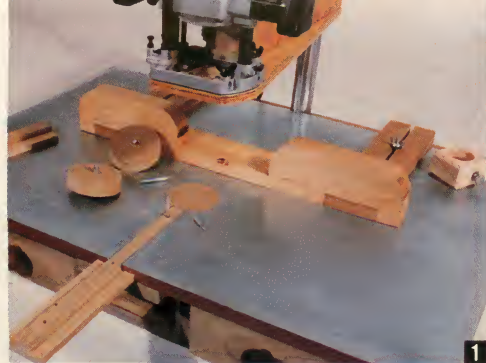
A commercial overarm router—which usually has an integral power head—is standard in furniture factories and top-notch cabinet shops. Their prices start at about \$2,000. But for negligible cost you can duplicate this homemade version that operates with your portable router.

Once I got the idea to build a router mount, I experimented a bit. The first design used a split-clamp to grip the router without its base. But every time I wanted to change the cut depth I had to loosen the clamp or move the support arm. For my second and final approach I mounted the router with its base on a plate. In this way the tool can be used normally for depth of cut. I used a plunge router to make it possible to preset depth of cut and also to duplicate cuts of similar depth.

Because of the plate, the router loses some depth of cut; but when the original capacity is 2 or 2½ inches, losing a half inch isn't critical—even when forming mortises. Capacity can be increased by mounting the router without its subbase and by substituting a thinner plate—perhaps ⅛-inch-thick aluminum.

While this project isn't difficult to build, it has some key details that require extra care. You might have trouble finding the thick-walled steel tube needed for the column, but if you check the *Yellow Pages* under "metal," you'll find a source, as I did—preferably one that deals with salvaged materials. Have the column and the router you plan to use on hand before you size components.

Cut the two back pieces to length and form the dadoes in the front one for the partitions. Then connect them with glue and No. 12×2½-inch flat-



The overarm pin router setup makes tricky tasks, like forming edge dovetail grooves, routine (lead photo). For greatest accuracy keep the edges of the workpiece square to adjacent surfaces and snug against the fence.

Accessories you build for the overarm router include a fence for straightedge or field cuts **1**, circular inserts with guide pins for pattern or pin routing, and an adjustable pivot guide for circular grooving or piercing.

When forming rabbets **2**, the fence position determines the width of the cut; the height of the cutter above the table determines its depth. When using the fence for edge shaping (not shown), the router bit cuts into the fence a little and the router mounting plate works like a hold-down.

The fence also ensures edge-distance accuracy when surface grooving in the field **3**. On jobs like this, and when rabbeting and shaping on adjacent edges, make the cross-grain cuts first. The final with-the-grain cuts will remove imperfections that inevitably occur at the ends of cross-grain cuts.

The pivot slide is used for accurate circular grooving **4**. The greater radius is measured from the center of the pivot point to the outside of the cutter. By substituting a plunge bit, this method can be used to form discs or large holes. Here, and elsewhere, move workpieces against the cutter's rotation.

For pin and pattern routing use an insert with a pin that matches the diameter of the cutter **5**. A pattern, or template, is tack-nailed to the underside of the workpiece. The height of the pin above the table should be less than the thickness of the template.

Moving the work so that the template bears constantly against the guide pin allows the cutter to duplicate the shape of the template **6**. It's helpful to practice first with the cutter raised. This same technique is used for, among other things, raising or incising letters, numbers, and designs.

exactly on the marked line. Remove the table and use a fly cutter or hole saw with a 1/4-inch pilot to enlarge the hole to a three-inch diameter.

Use a table saw to make the 3/4-inch-wide cut that ends at the hole. Then with the blade projecting 3/8 inch, make repeat passes to form the "T" shape for the pivot slide (see detail A). Cut the slide support and, after forming the two-inch hole and installing the T-nut,

Continued

router

head screws. Be certain the bottom edge of the assembly is flat and square to adjacent sides. If it isn't, the 1 1/2-inch hole needed for the tube will not be true. After boring the hole with a good spade bit mounted in a drill press, test-fit the tube and check that it's perfectly vertical with a square. Drill for and install the 3/8-inch threaded insert for the bolt that secures the tube.

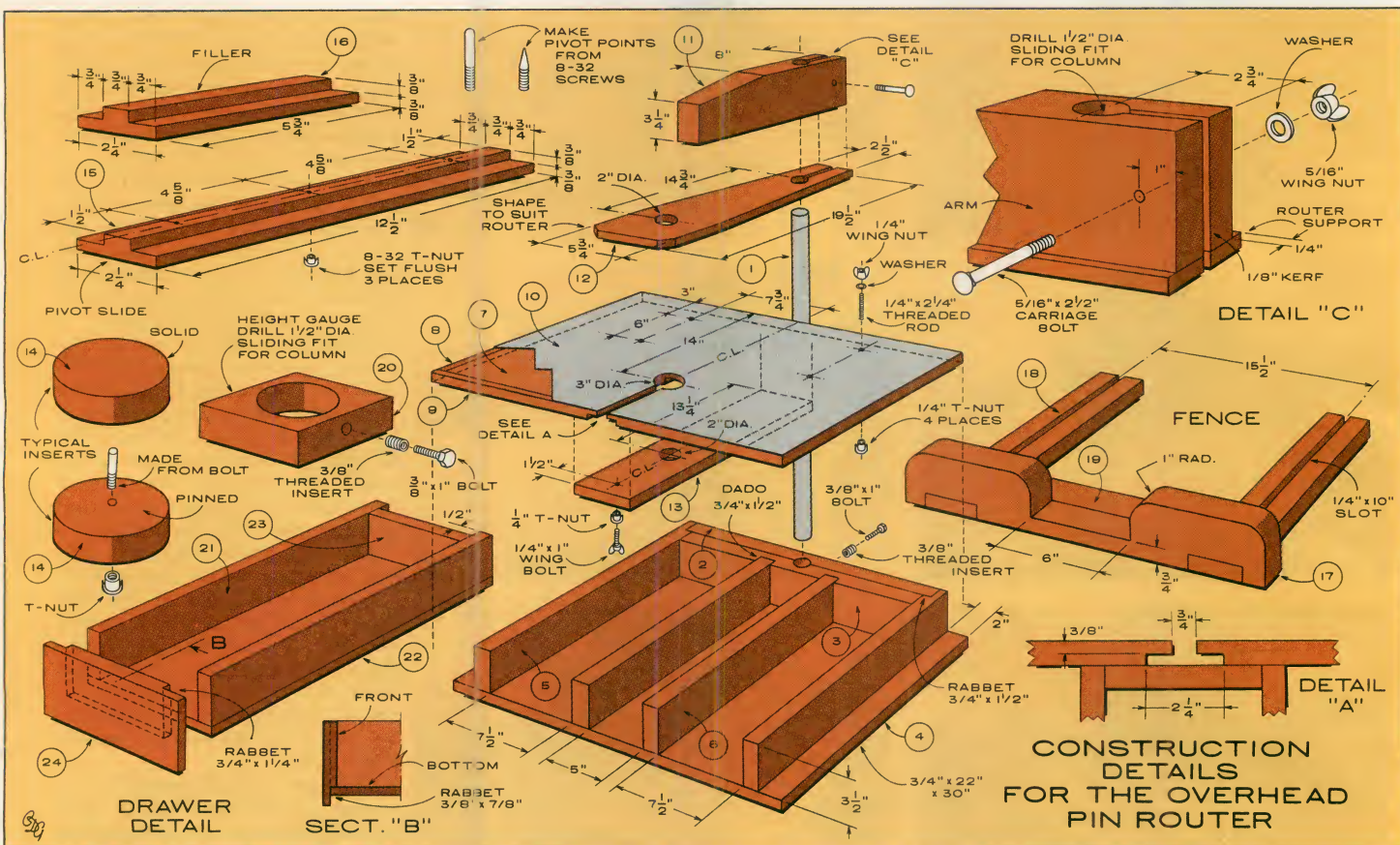
Size the base, rails, and partitions and assemble all the parts by using glue and driving No. 10 x 1 1/2-inch flathead screws up and through the base.

Use a cabinet-grade maple or birch plywood when you are making the table. Cut it to size, add the side and front trim strips with glue and 4d finishing nails, and then attach the aluminum cover with contact cement.

The next steps, forming and assembling the arm and the router support plate, require extra care—especially

boring the hole through the arm. It must be vertical and provide a snug fit for the column. The dimensions given for the plate are for the router I used; but it's best to check its length and its front-end shape against the tool you will install. Bore the two-inch hole so it will be on the plate's centerline and concentric with the router's chuck. After forming the rear hole for the column, attach the plate to the arm with glue and three No. 10 x 1 1/2-inch flathead screws. Finally, form the kerf at the rear of the assembly and drill the hole for the 5/16-inch carriage bolt.

Secure the column in the base and slide on the arm assembly. Place the table, which butts against the column, so it is square to the substructure and its centerline matches up with the center of the column. Mark the line lightly with a scribe; then, with a 1/4-inch plunge-point router bit mounted, use the router to bore through the table



attach it to the underside of the table with glue and several No. 10×1/4-inch flathead screws. The last table detail is to install the four 1/4-inch T-nuts for the threaded rods that are used to secure the fence. The T-nuts do not have to be set flush because the height of the drawers allows for clearance.

Coat all of the top edges of the substructure with glue, assemble the table accurately, and then use clamps around the perimeter and whatever weights are handy at the midpoints.

Accessories

Use a piece for the pivot slide that is long enough so that after shaping you can cut off a section as the filler. Three T-nuts (and these must be installed flush) are used in the slide for more flexibility when establishing the distance from pivot points to cutter. Pivot points, some long enough to penetrate workpieces, others short and pointed when a center hole isn't wanted, are made from 8-32 screws.

It's best to use a fly cutter with a 1/4-inch pilot drill to form the inserts because this will allow sizing them for a snug fit in the table hole. The hole in the insert can be enlarged to suit the pins—made from bolts—that you will use. Plug the hole in one insert with a dowel; drill others and install suitable T-nuts for 1/4-inch, 3/8-inch, and 1/2-inch pins.

When you are making the facing for the fence, form the wide dados for the guides before reducing the center area. Make this area wide enough so that the router plate can sit on the ledge—because there will be times in the future when it's necessary to bring a router bit as close to the table as is possible. Attach the slotted guides to the facing with glue and No. 10×1/2-inch flathead screws. The stiffener can be attached with glue.

The height gauge—which is placed on the column between the arm and the table—is optional, but can be handy when you wish to return the arm to a specific height after making an adjustment.

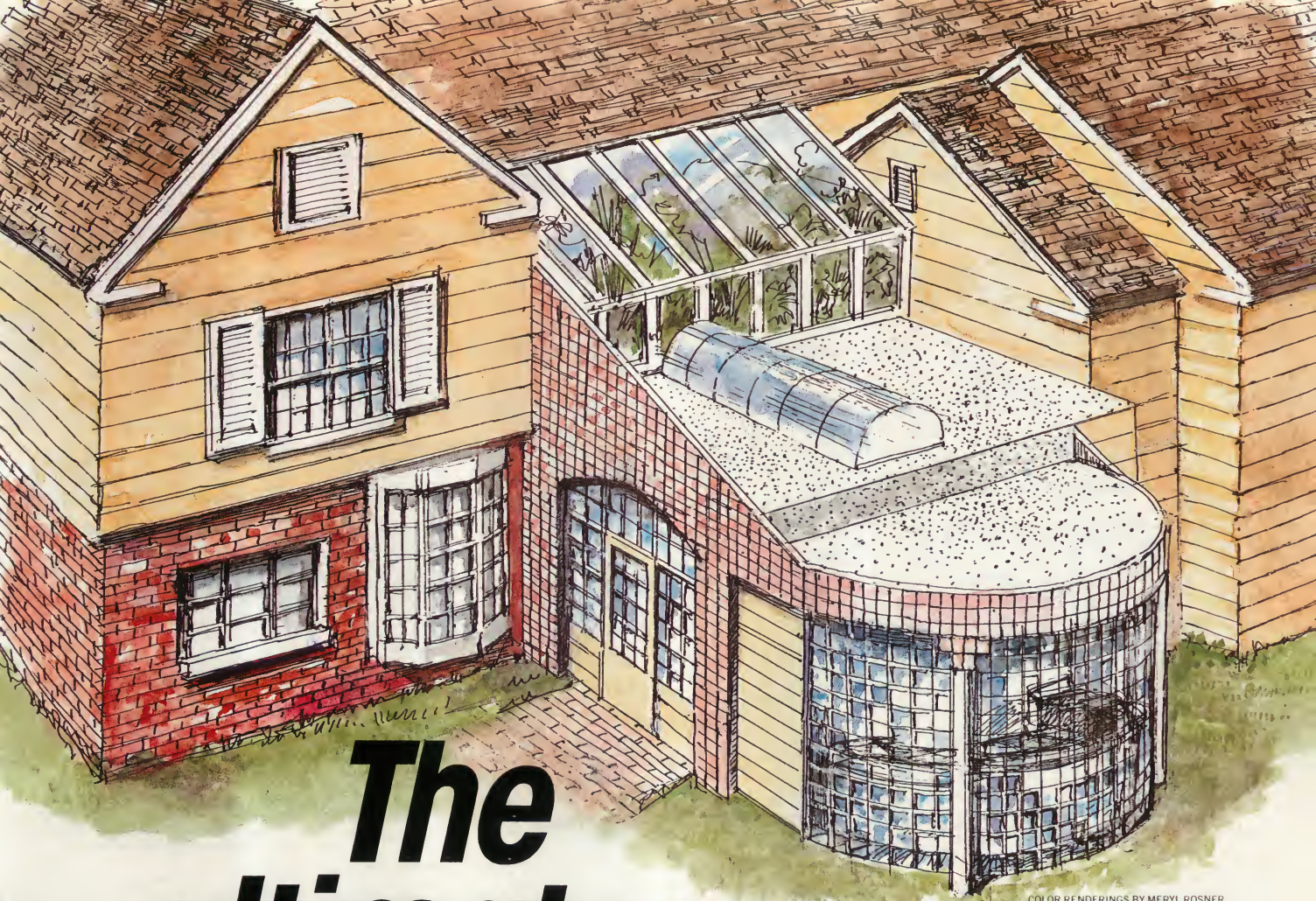
Always be sure the bolt that secures the column at its base and the carriage bolt that locks the arm are tightened before beginning a job. If you find that the wing nut for the carriage bolt doesn't allow sufficient tightening, substitute a nut that you can turn with a wrench.

Using the router with its base affords the same protection you would have when using the tool normally. If your router has a plastic shield, use it. In any case, having hands close to a cutting area is ill advised, as always. Be safety conscious—take precautions such as unplugging the tool before making any adjustments or changing cutters.

MATERIALS LIST

KEY PART	NO. PCS	SIZE	MATERIAL
1 column	1	1 1/2" o.d. x 24"	steel tube
2 outside back	1	1 1/2" x 3 1/2" x 24 1/2"	straight grain fir
3 inside back	1	1 1/2" x 3 1/2" x 23"	straight grain fir
4 base	1	3/4" x 22" x 30"	plywood
5 rails	2	1 1/2" x 3 1/2" x 22"	straight grain fir
6 partition	2	1 1/2" x 3 1/2" x 19 3/4"	straight grain fir
7 table	1	3/4" x 20 3/4" x 31"	cabinet-grade plywood
8 trim	2	1/2" x 3/4" x 20 3/4"	pine
9 trim	1	1/2" x 3/4" x 32"	pine
10 cover	1	0.025 x 21 1/4" x 32"	aluminum
11 arm	1	2" x 4" x 15 1/4"	hardwood
12 router support	1	1/2" x 5 3/4" x 19 1/2"	hardwood
13 slide support	1	3/4" x 5" x 20 1/2"	hardwood
14 inserts	*	3/4" x 3" d.	hardwood
15 pivot slide	1	3/4" x 2 1/4" x 12 1/2"	hardwood
16 filler	1	3/4" x 2 1/4" x 5 3/4"	hardwood
FENCE			
17 facing	1	1 1/4" x 3" x 21"	hardwood
18 guides	2	3/4" x 3" x 12"	hardwood
19 stiffener	1	3/4" x 1 1/2" x 12 1/2"	hardwood
20 height gauge	1	1" x 2 1/2" x 2 1/2"	hardwood
DRAWER			
21 sides	4	3/4" x 2 7/8" x 18"	plywood
22 bottom	2	3/8" x 7 1/2" x 18"	particleboard
23 back	2	3/4" x 2 7/8" x 6"	pine
24 front	2	3/4" x 3 3/4" x 8 1/2"	pine
HARDWARE			
5	1/4" T-nuts		
3	8-32 T-nuts		
2	3/8" threaded inserts		
2	3/8" x 1" bolts		
1	5/16" x 2 1/2" carriage bolt w/washer and wing nut		
4	1/4" x 2 1/4" threaded rod w/washers and wing nuts		
1	1/4" x 1" wing bolt		
2	drawer pulls (your choice)		

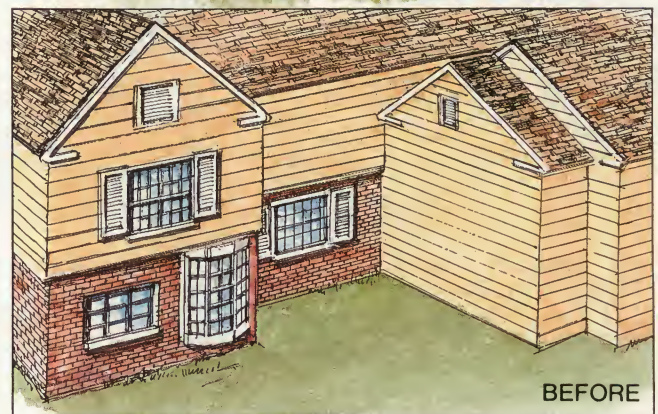
MISCELLANEOUS: T-nuts for inserts, 8-32 screws for pivot points. No. 10×1 1/2" flathead screws, No. 10×1 1/4" flathead screws
* As needed



The ultimate family room

By AL LEES

Though construction bids came in over what the homeowners had budgeted for the project, architect Andy Pressman's design for splicing a family-room wing onto the rear of this house is so full of verve that *POPULAR SCIENCE* decided to give you a look at this unbuilt addition in hopes it contains ideas you can borrow for your home.



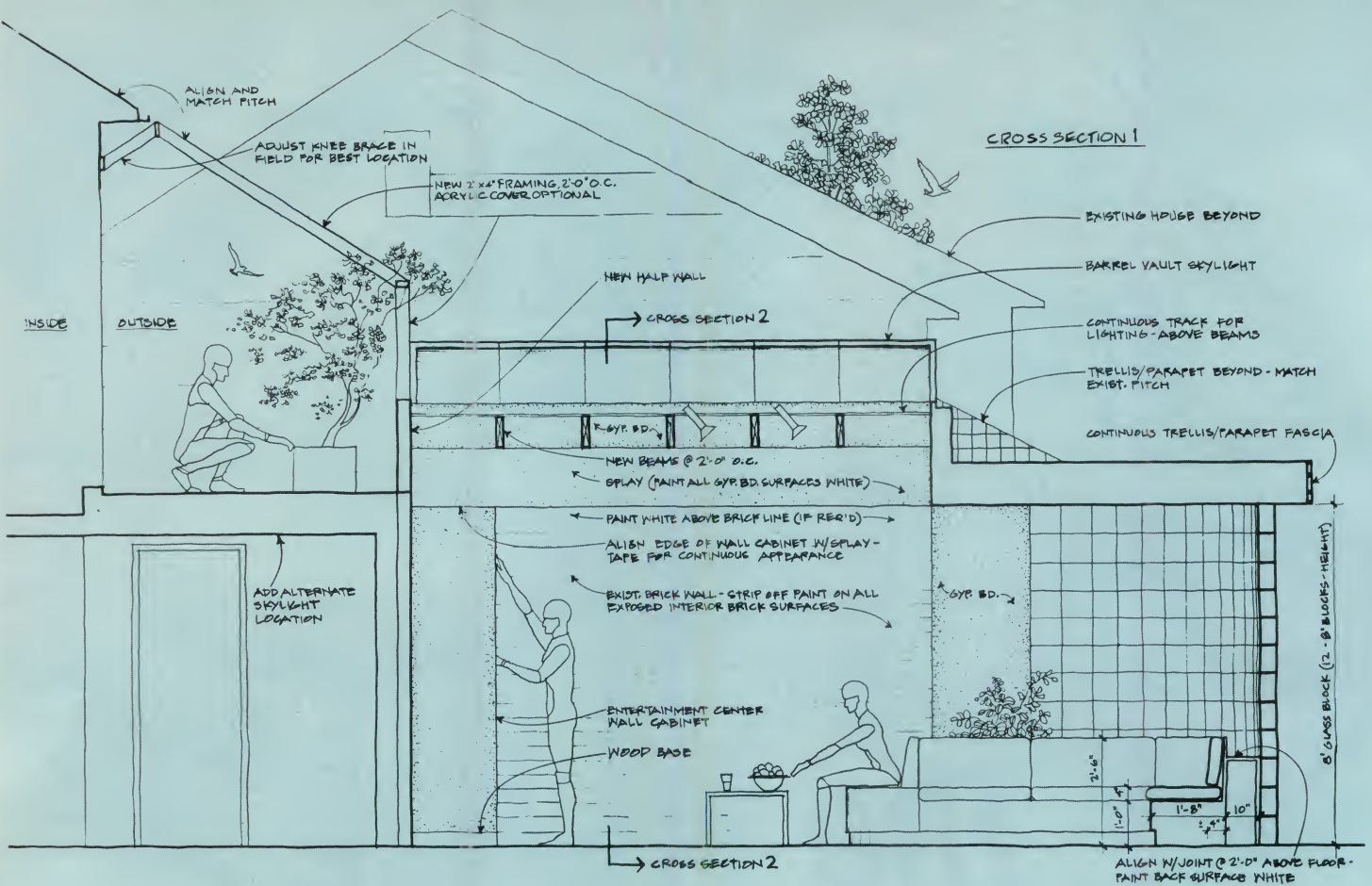
When architect Andy Pressman was asked to remodel the back of a home on the North Shore of Long Island, N.Y., the challenge was to tie a family-room addition into the existing architecture.

"The clients wanted a place of relaxation and leisure," Pressman reports, "a den conducive to reading, TV watching, listening to music... with provision for cocktails-before-dinner entertaining."

His solution was to create an entry axis for the new space, reinforced visually by a barrel-vaulted skylight, off which he could provide distinct functional zones. This would terminate in a glass-block apse that would admit daylight while preserving privacy.

"On the outside, airy wood framing would reconcile the awkward juxtaposition of existing roof lines and exterior surfaces," Pressman explains. "A trellis wraps around the exterior, matching the present roof pitch and touching

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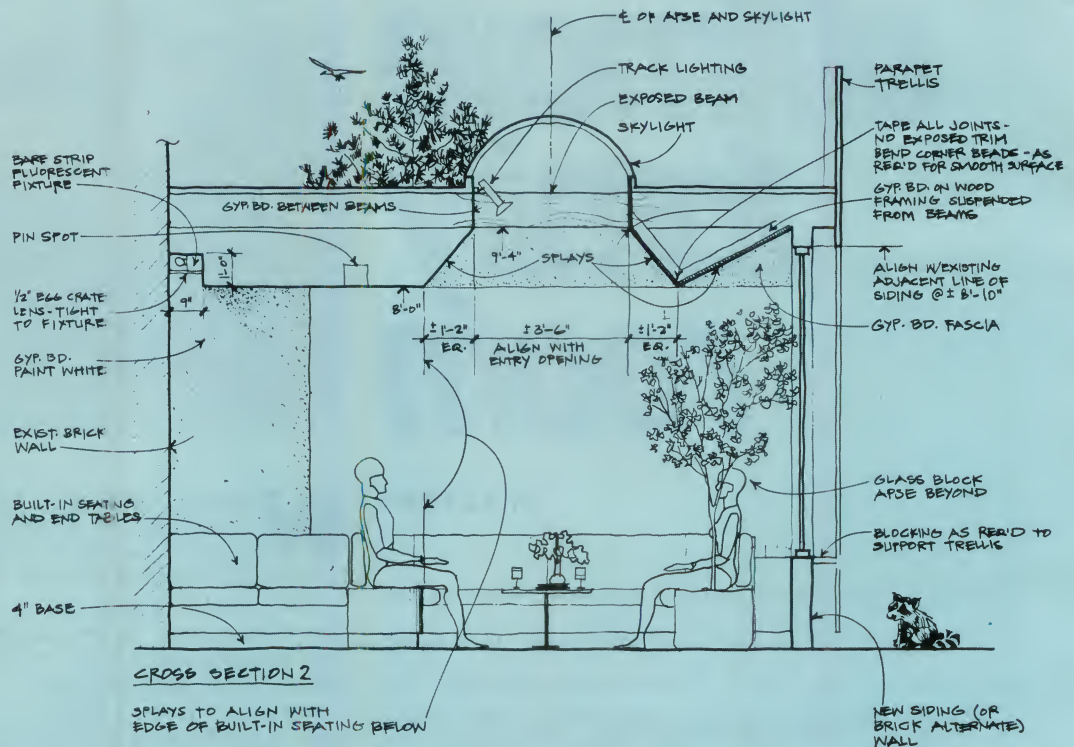


the ground in an arch around the new entry door. My choice of materials conformed to the character of the rest of the house."

After preparing a portfolio of proposed floor plans and elevations (three of which are reproduced here), Pressman further clarified his presentation with a scale model of the existing house, with the proposed room added. Charmed, the clients agreed to a broad construction-budget range: between \$30,000 and \$50,000. But when the bids came in from competing contractors — consistently at mid-point (about \$40,000)—the clients balked.

Such things happen. But when Pressman showed the design work to *POPULAR SCIENCE*, the editors felt the project was too good to waste, and commissioned color renderings to show how it would have looked.

Pressman was working with more than budget restraints on this project. He'd been asked to keep the increase in volume as low as possible because his clients felt the architectural review board in their town would reject a more



massive addition. Pressman's addition minimizes bulk by rounding off the end wall with a glass-block apse, the roof of which is stepped down from the skylighted section.

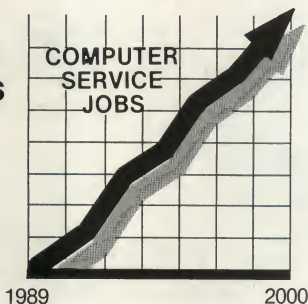
Though a flat roof was kept on the entire wing, the new structure was tied into the old visually by means of a sloping non-structural trellis to match an existing roof pitch. This trellis was to be constructed of redwood 1×1s

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5 sure steps to a fast start as a high-paid computer service technician

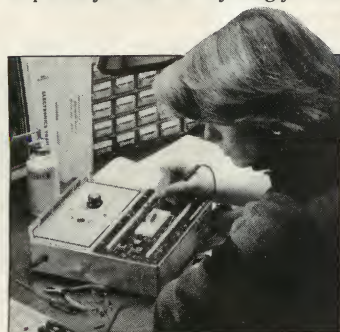
1. Choose training that's right for today's good jobs

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If you really want to get ahead in computer service, you have to get inside a state-of-the-art computer system. That's why NRI includes the powerful new Packard Bell VX88 computer as the centerpiece of your hands-on training.

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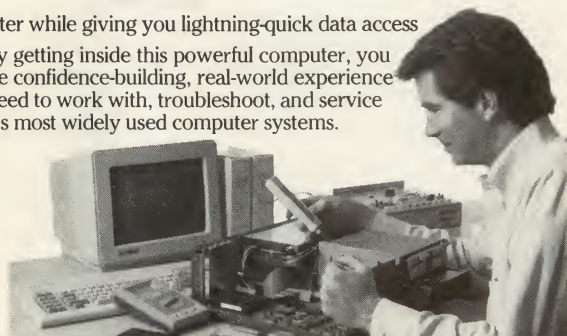
You assemble and test your computer's "intelligent" keyboard, install the power supply and 5¼" floppy disk drive, then interface the high-resolution monitor. But that's not all.

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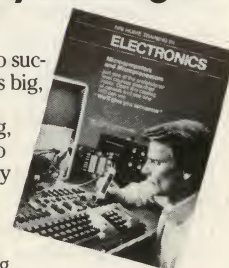


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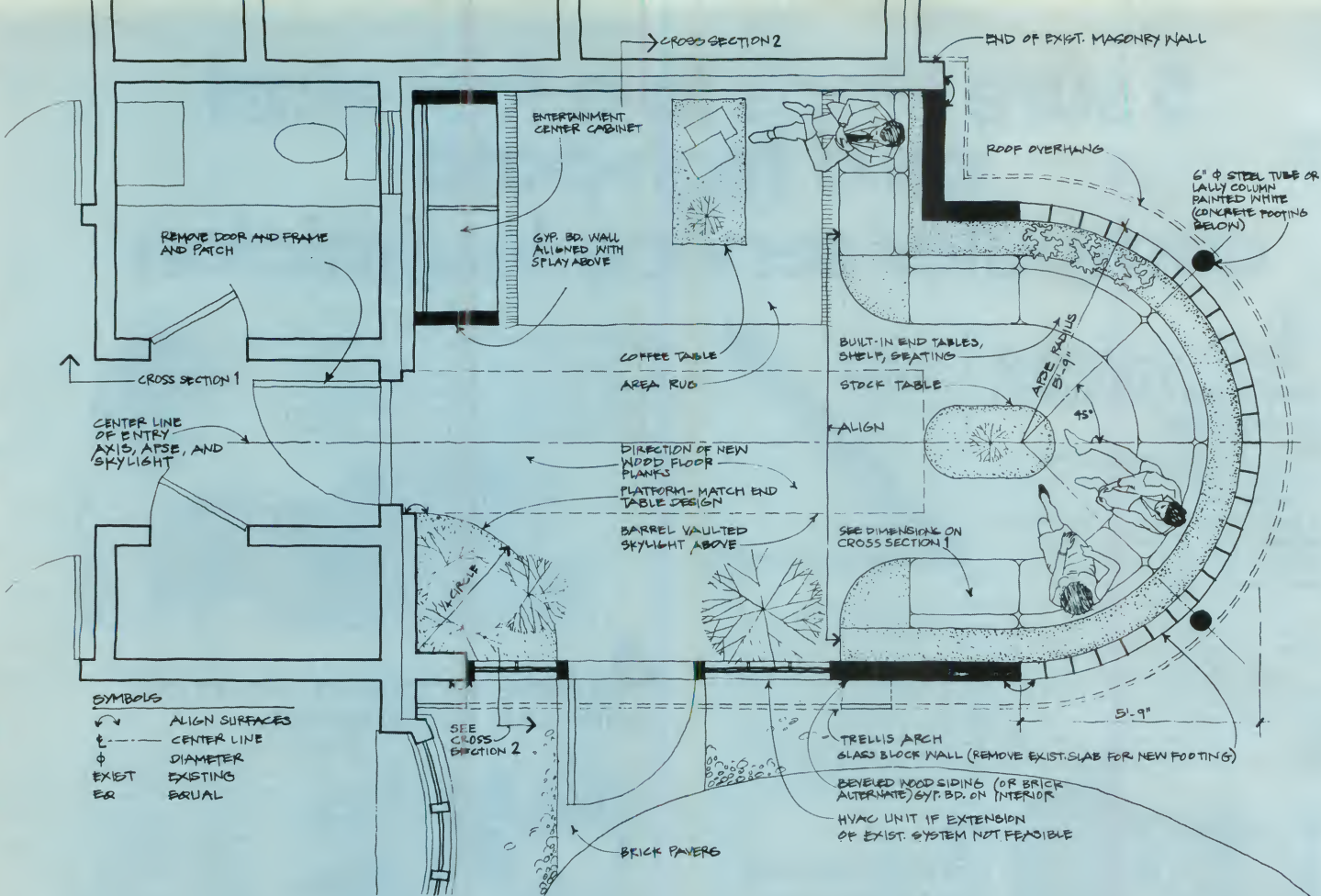
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nailed on four-inch centers. Where the trellis follows the apse curve above the glass block, curved horizontal slats will have to be cut from larger 2× redwood boards, with the joint lines hidden behind vertical members. Or you might elect to go to thinner stock so slats can be soaked and bent to this radius, then attached to the fascia board with 1×2 blocking, aligned behind vertical slats.

The entry arch gives a French styling to the 15-light door flanked by matching casements, with fixed strip windows above—all in double-pane insulating glass. The top of the arch aligns with the top of the window frame. “By combining standard off-the-shelf window and door units with the floating trellis,” Pressman points out, “I created the illusion of arched glazing without the structural complexity and cost of the real thing. The arch motif recurs in the barrel-vaulted skylight—a custom unit.”

Pressman called for open 2×4 framing around that section of the roof deck that’s accessible from an upstairs hall. *POPULAR SCIENCE* felt this provided an ideal spot for a small sunspace, so the editors chose to indicate glazing in the framing. (The pitch is steep enough to shed snow, but you still might want to bulk up the framing to 2×6s to carry the glazing.) The headroom at the knee wall is *cramped*. This space is intended for sunning on a mat or for planters, as shown in cross section 1.

Special lighting for the den

Because of the room’s multiple uses, the clients asked for a versatile lighting plan. As shown in cross section 2, a recessed cove light washes the existing brick (now an interior wall), highlighting its rich texture and color. Six track lights are mounted high to utilize exposed beams as natural baffles that reduce glare. Skylight splays are designed to maximize penetration of natural light as well as to enhance the ceiling sculpturally. The gypsum-board ceiling

was to be taped smooth for a continuous appearance. For greatest flexibility, the fluorescent fixtures, the down lights, and the track lighting were all to be on separate switches.

The client’s backyard was wooded, so a deliberate effort was made to create the effect of a tree house. Overhead leaves dapple the skylight; the floor-to-ceiling glass-block wall filters a view of greenery while it wraps around a circular seating area. Because the total area of blocks is only 144 square feet, no intermediate expansion joints are required, according to the manufacturer’s installation instructions.

The semicircle of built-in benches creates an ideal conversation area—perfect (with a centered table) for those cocktails before dinner. And if the homeowner installed low-voltage outdoor lighting to illuminate trees and shrubs beyond the curve of the glass block, the nighttime effect could be sheer magic from inside.

Note from the bench dimensions in cross section 1 that for comfortable seating there’s a 10-inch-wide ledge recessed behind the seat backs. This ledge should be painted white for best appearance through the glass block. Construction of the curved bench could be of plywood or tempered hardboard—or a combination. Curving of vertical members can be achieved through kerfing on the inside face or by soaking panels before nailing them to a supporting frame, bending as you go.

The floor plan above makes clear how separate areas are created for different functions. The entertainment center alcove is removed from all traffic lanes, so no one will pass between the viewer and the TV screen. The couple seated in the apse is far enough away to converse without distracting the TV viewer. There’s ample seating throughout for listening to music.

All in all, it’s an addition that’s as practical as it is handsome.

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See NASA Tech Briefs for technical details, 1986, 1987 and 1988.

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Metal stitcher

A new pulsating stitch-welder attachment makes arc welding thin-gauge sheet metal fast and easy. It also reduces metal distortion and burn-through.

By PHIL McCAFFERTY

Most auto-body repair work—on quarter panels, body patches, or floor boards, for example—requires some light welding that ordinary arc welders can't handle because their current output can't be set below 80 amperes. At 80 amps and above, they tend to burn through and distort sheet metal thinner than $\frac{1}{4}$ inch. But I was able to do practically distortion-free welds without burn-through on 22-gauge (0.0313-inch) steel thanks to an attachment called a stitch welder.

Designed primarily for auto-body

repair, it is also a fine device for working with thin metals in other applications, and it has obvious uses in metal sculpture. The stitch feature can also be used on heavier work to a certain extent.

The \$59 stitch-welder attachment is a pistol-like device that connects to your AC arc-welder electrode holder with a five-foot power cord. Despite the moniker, it doesn't actually stitch metal together—it welds it. The welder's high amperage is controlled by an electrical solenoid and a diode circuit in the stitch welder.

The solenoid, housed in the cast-aluminum body, creates a pulsing ac-

tion in both the electrode and the arc and causes the welding rod (chucked in the end of the armature) to oscillate rapidly with a stroke adjustable from about $\frac{1}{16}$ to $\frac{1}{8}$ inch. The automatic, almost imperceptible stitching action reminded the inventor of a sewing machine needle, hence the name.

The diode is housed in the vinyl-insulated grip. When switched on, it cuts amperage output by half. Whether you need the reduction diode depends on the amperage you need and what your welder is capable of. Generally, 18- to 22-gauge material will require 40 to 50 amps and $\frac{1}{16}$ - or $\frac{5}{64}$ -inch rod. So if 50 amps are needed, for example, and your welder doesn't go that low, set the amperage at 100 and switch on the diode to reduce output to 50. The stitch welder is intended for use on AC welders that can't run below 80 amps. If used on a small 110-volt AC welder, you must disable the solenoid because it will not strike an arc in the pulsed mode.

You probably won't notice the in-out stitching action when you weld. That's because while the easy-to-form-and-maintain arc never appears to break, it does. And the rapid motion—the stitch-welder attachment pulses thousands of times per minute—delivers a smooth, even bead. Like any other welding process, it takes practice to produce good results. The chuck on the stitch welder will take from $\frac{3}{32}$ - to $\frac{1}{16}$ -inch-diameter standard arc-welding rods, which should allow you to handle work from 22-gauge up to $\frac{3}{16}$ -inch steel.

The supplier, The Eastwood Co., strongly recommends the use of mild steel rods such as 6013 and 7014 on thin sheet metal. Eastwood sells a special $\frac{5}{64}$ -inch rod that works well with the attachment. (It's \$13 for approximately 120 rods.) The Eastwood Co., 580 Lancaster Ave., Box 296, Malvern, Pa. 19355. P 3

Stitch-welder attachment controls amperage output through an electrical solenoid and diode reduction circuit. The generated pulsing action can "stitch" weld metal as thin as 22 gauge—perfect for fine auto-body applications.





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ICC's paints have been tested by the Army, Navy and Marine Corps and is being used extensively by each. It has been laboratory tested for its thermal properties, fire resistance, hail resistance, water penetration resistance, corrosion resistance and many other very pertinent tests, in fact these accredited laboratory test results compile a test book over an inch thick. ICC's paint has been tested and compared to present space craft paints by TRW, a U.S. Government contract Starwars testing facility. TRW's statement: "Your paint appears to have very good thermal properties as applicable to spacecraft usage."

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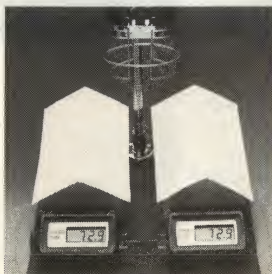


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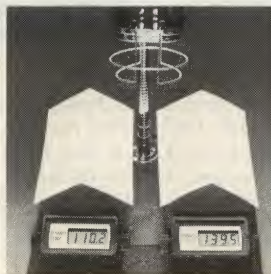


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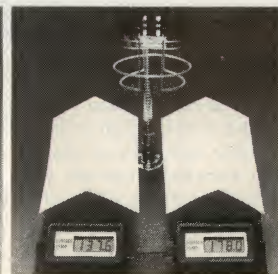
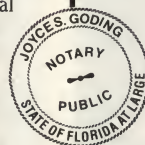


PHOTO 3

These are *identical* miniature buildings made of plastic with galvanized metal roofs. Heat sensors have been fastened to the inside of each roof and attached to digital thermometers. A 600 watt photo lamp is located midway above and at equal distance from each model. The roof on the left is painted with ICC's paint; the other with high quality reflective white building paint. Photo #1 shows under roof ambient temperature before test lamp is turned on; after two minutes with bulb on (Photo 2) shows a 29.3 degree difference and after three minutes the difference is an almost unbelievable 40.4 degrees. This is a demonstration test you can do in your customers' living room or office. Imagine the impression — and sales this demo will make for you.



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We've all heard stories of people who made fortunes cashing in on the many scientific breakthroughs. Now thanks to ICC's new space-age paint you may have your chance if you qualify.

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What's New



Swedish fighter's maiden flight ▲

The JAS 39 Gripen flew for the first time a few months ago. Flight testing will continue until 1992, when the aircraft is due for delivery to the Swedish Air Force. The light multi-role combat aircraft was designed by an industry group including Saab Aircraft Division and Volvo Flygmotor AB.



Heads up ▲

When SOSpenders' (\$60 to \$68) inventor saw a fly-fishing buddy drown, he vowed to make an inflatable life preserver comfortable to wear over chest waders. A tug on the handle activates a replaceable carbon dioxide cartridge. Sporting Lives, Box 518, Meridian, Idaho 83642.



Off-road vehicle has wheels plus wings ▲

Flying automobiles have been around for more than 20 years. Above is a scale model of the latest version, the Aerocar CPX. It would be kit-built and classified as an experimental aircraft to comply with federal regulations for both planes and cars.



Hydroplaning razor ▲

A patented blue strip on the Ultra Glide twin-blade razor is coated with a material that's twice as slippery as Teflon, says Wilkinson Sword. The strip, which absorbs water to create a hydroplaning effect, leaves no residue on the skin. Cartridges will be sold for fixed and pivoting razor heads.



◀ Target tracker

The first production unit of GE Aerospace's Multiple Object Tracking Radar was delivered last year to the U.S. Army's White Sands missile range. The transportable radar, which takes 24 hours to set up, has an electronically steered antenna that can track as many as 10 targets at once.



Airless tires ▲

Cyclists using polyurethane microcellular foam tires don't have to worry about flats. The tires, made by a centrifugal casting process, simulate the cushiony ride of a pneumatic tire. Sold in China now, they'll soon be produced in the United States and Canada.



Road research ▲

Laser guns housed in this 14-foot flatbed bounce light beams off road surfaces to measure bumps, rutting, and curvature. Developed by Britain's Transport and Road Research Laboratory, the trailer travels at 50 mph.

Cycling stereo ►

It's dangerous (and in some places illegal) to wear headphones while riding a bicycle. But you can take your personal stereo on the road with the \$37 TUNE-Tote 2. Mounted on your handlebars, brackets hold weather-resistant two-inch speakers driven by a battery-powered amplifier. Serus, 9076 Carroll Way, San Diego, Calif. 92121.



People mover ▲

Cars like this one will carry passengers at the Yokohama Exotic Showcase (an expo with "space and children" as its theme, beginning this month) in Japan's second largest city. Made by a French company, Soule, the SK System cars hold 10 to 20 people and travel about 18 seconds apart at 12½ mph.



Player piano ►

Yamaha's Disklavier piano requires no pianist—just a 3.5-inch floppy disk. You can change key or tempo, cancel parts, or record your own pieces. Optical sensors convert the movements of keys and pedals into digital signals, and solenoids behind the keys use the signals to play the music. The acoustic piano has a remote control. The price range is \$8,000 to \$9,000.



What's New HOME



◀ Overheating alarm

Using a bimetal sensor to detect temperatures above 575 degrees F, Hot Button alerts you with an alarm and a red light when your stovepipe gets hot enough to ignite creosote in the pipe and cause a chimney fire, says Consumer Products International (Box 410, Skaneateles, N.Y. 13152). The battery-powered device attaches to the stovepipe with a magnet. Price: \$30.

Motor bed ▲

Three electric motors contour each slatted base of this German-made bed, with independent controls for each side. A push-button key pad provides remote operation. The battery-powered motors are encapsulated for quiet operation. Battery recharging is needed after about 50 adjustment movements, says Profiles (200 Lexington Ave., New York, N.Y. 10016). Price: up to \$6,200.



Rust stopper ▶

Initially developed for industrial use, Zintex rust converter is said to alter the rusting process through a chemical conversion by removing oxygen and forming a nondestructive coating of hematite or magnetite, similar to black oxide plating. T. N. Cowan Co., Box 900-43, Alvarado, Texas 76009-0900; \$34 per half gallon.



Sliding hood ▲

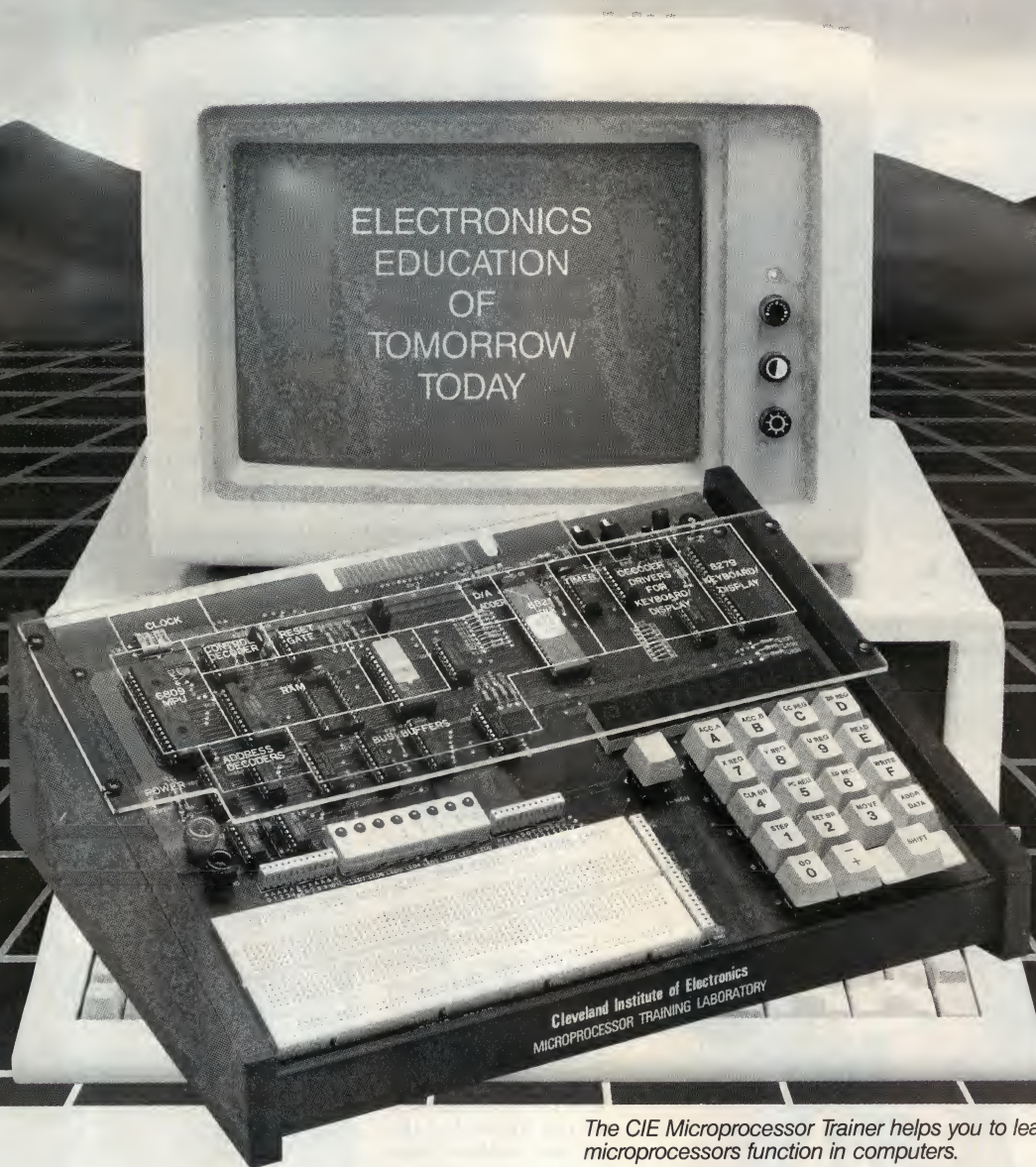
The Sears Limited Edition range hood slides to hide under a standard 30-inch cabinet. Pulling it out activates the blower and light; pushing it in turns them off. The 300-cubic-foot-per-minute dual blowers exhaust vertically through external ductwork. \$280.



◀ Computer-designed gas fireplace

The Mendota Gas Hearth is a gas-fired zero-clearance fireplace that delivers 40,000 Btu per hour at 75-percent efficiency. Computer imaging and modern materials were used to design a realistic log fire, says the company. Mendota Forge Corp., 1890 Wooddale Dr., St. Paul, Minn. 55125; \$1,400.

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What's New PHOTOGRAPHY



Autofocus SLR ▲

The latest entry from Pentax in the auto-everything single-lens-reflex derby is the SF10. It uses a phase-matching autofocus system that can be manually overridden, has nine auto-exposure modes, and sports a retractable automatic flash.



Superpro SLR ▲

Nikon's famed F series of SLRs has always been targeted primarily at the professional photographer. That makes one feature of the new F4 particularly notable: It's an autofocus camera, indicating that some pros' resistance to the idea of autofocus may be waning. Features include a new $\frac{1}{8,000}$ second shutter; three metering systems; a built-in coreless motor for continuous shooting at up to 5.6 frames per second; and a durable cast-aluminum body. Price of the Nikon F4 for the body alone is about \$2,400.



Remote 35 ►

Canon's clever new point-and-shoot 35, dubbed the Sure Shot Ace, has two unusual features: a waist-level finder that is a great help in ground-level or over-the-head shots and a neat detachable remote controller that lets the photographer put himself in the picture without having to race against the self-timer.



◀ Body-hung tripod

The Freshold Optical Support has two telescoping legs, with a neck band taking the weight of the camera. The unit prevents the blur associated with slow shutter speeds and long lenses. In Court Sports Ltd., Box 28, Chepstow, Gwent NP6 6XE, England.



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What's New TOOLS

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With sawhorses, a platform, your portable circular saw—and Sawmate—you can do crosscuts (up to 14 inches wide), rip cuts (to widths of 10½ inches), left and right miter cuts—even bevels and compound miters. The portable jig weighs 48 pounds and sells for \$295. Sawmate, 6144 88th St., Edmonton, Alberta T6E 5H7, Canada.



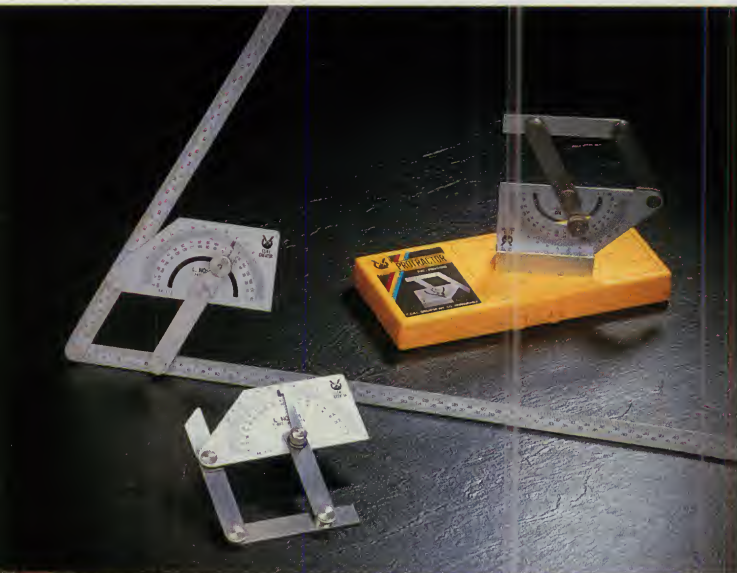
Little angler ►

A new right-angle-drive from AEG lets you use your cordless screwdriver where you couldn't before: in tight spots, under edges, even in channels. It takes standard ¼-inch hex bits. The thumb flange, which rotates 360 degrees, provides torque control. AEG Power Tool Corp., 3 Shaw's Cove, New London, Conn. 06320; \$22.



Gotta know the angle? ▲

This flexible protractor with parallelogram arms has multiple straightedges for measuring all manner of internal and external angles. Four different scales cover the extensive range of possible readings. The standard version is in front; at rear right it is shown in the screw-on base, which allows for free-standing measurements and centering on cylinders. A long-arm version is at left. CCKL Creator International Co. Ltd., Box 67-1340, Taipei, Taiwan, R.O.C.



◀Cutting remarks

Disston's new line of Tiger Force carbide saw blades includes a deck blade (left), made for treated lumber. Its non-stick coating reduces residue buildup and friction. The blade on the right has variable teeth. The result is improved chip clearance and faster, smoother cuts, it's claimed. The Disston Co., Rte. 29 N., Danville, Va. 24540.



Shop Ferris wheel ▲

Here's a new gadget made to hold nails, screws, nuts, and bolts that are in need of an orderly home. Stor-master's octagonal drum holds 32 plastic jars. An indexing feature keeps the drum from rotating, so the heaviest row won't fall to the bottom. Stor-master is \$29 from U-Neek Products, Box 8246, Cherry Hill, N.J. 08002-0246. It will be sold in stores later in the year.



How to solve the energy crisis.

If you're like a lot of people the energy crisis has nothing to do with oil embargos and solar power.

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What's New ELECTRONICS



Grand sound ▲

It sounds like a seven-foot grand piano, claims maker Ensoniq, but the secret to the 54-inch digital keyboard is its Bose Acoustic Wave speaker system, which delivers the tone, timbre, and resonance of a traditional piano. Price: \$3,000 from Ensoniq Corp. (155 Great Valley Pkwy., Malvern, Pa. 19355).



Printer plotter ▲

The EOgraph Plus circuit board plugs into your PC. Result: Your printer becomes a plotter that can produce high-resolution drawings up to 15 feet long. According to maker Eotron Corp. (121 Westpark Rd., Dayton, Ohio 45459), the board can emulate DM/PL and HP-GL plotter languages. It's \$729.

◀ Dazzling data disks

Get organized: Sony's 3.5-inch floppy disks come in red, yellow, blue, green, and white so you can color-code the data they contain. The double-sided double-density disks are available in packs of 10 for \$40.



Play-all ▲

Philips' CDV488 optical disc player handles all six audio and video formats: three-inch single CD, five-inch CD, five-inch CD-V, 8- and 12-inch laser video, and the new eight-inch laser-disc single that contains 20 minutes of audio and video. Price: \$1,300.

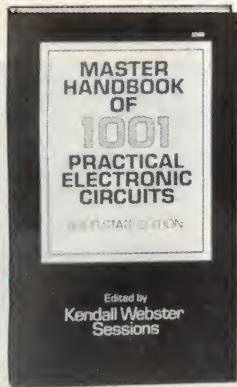
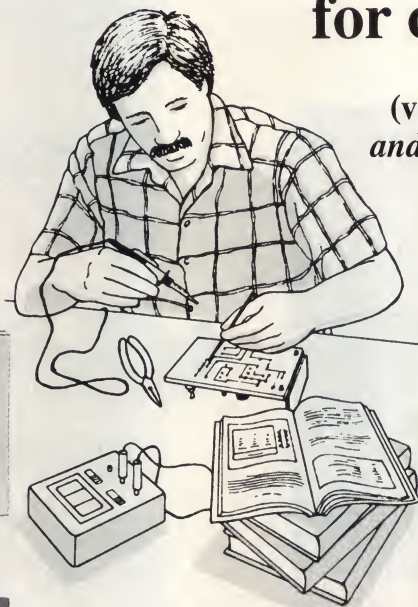
Color videophone ▶

Smile. In about one minute a high-resolution color picture of you is sent via standard phone lines to another Kodak still video transceiver. Pictures from VCRs, discs, cameras, or video imaging devices can be exchanged too. Price (stop smiling): \$14,400.



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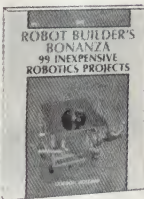
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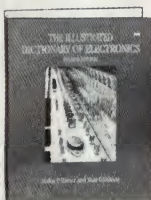
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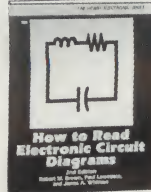
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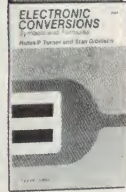
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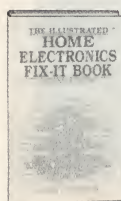
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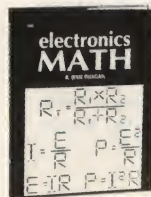
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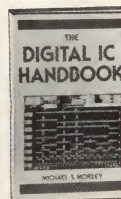
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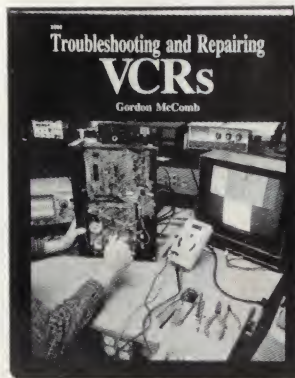
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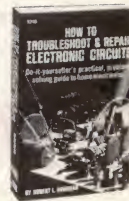
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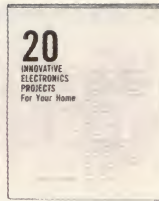
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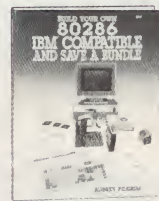
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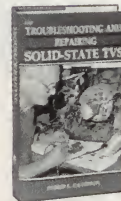
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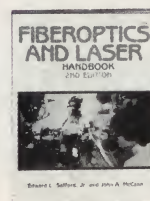
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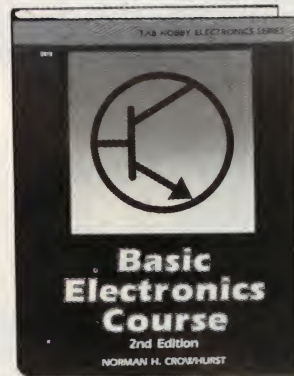
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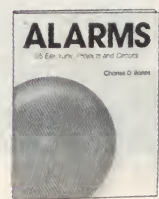
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What's New RECREATION



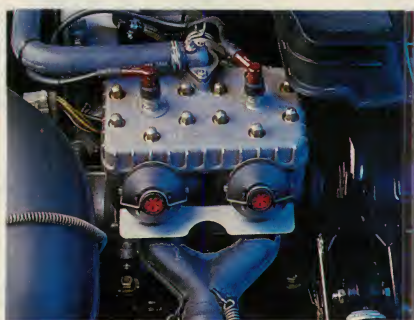
▲ Instant camp

Stowed, this 250-pound camping rig has the looks and aerodynamics of a camper shell. Opened up, it offers the roominess of a pop-up camper, says WilderNest (1425 S. Acacia Ave., Fullerton, Calif. 92631). It's \$2,500 to \$2,900, depending on truck size.



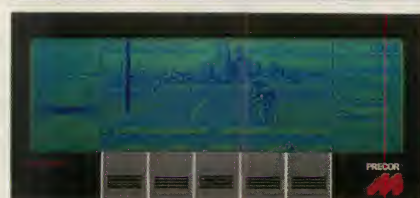
◀ Flexible power

The 580-cc engine in Ski-Doo's Formula Mach 1 sled has guillotinlike automatic valves that vary exhaust-port size with rpm for strong performance at both low and high speeds, according to Bombardier (Valcourt, Quebec, JOE 2LO, Canada). It costs \$6,000.



Footlike shoes ▶

Complex construction of the Torsion running shoe's sole allows it to twist slightly as your forefoot and heel do when they contact the ground. Less stress and better traction result, says Adidas. Pictured here is the \$100 women's Model 8020. Adidas, Box 4903, Warren, N.J. 07060.



Racing in place ▲

Telephone poles rush by, a thunderstorm is brewing, and your opponent just ahead is infuriatingly hard to catch. The liquid-crystal display on Precor's M8.7sp stationary cycle shows you all this plus extensive performance data. Precor USA, Box 3004, Bothell, Wash. 98041-3004. Price: \$2,195.



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over rocks and gulleys on the way to a landing where it will take on 80,000 pounds of Douglas fir logs. As he approaches the landing, the driver hits the switch again, this time pumping the tires up to 65 psi. By the time he drives back

onto the pavement the tires are back up to 80 pounds, and the truck is off and running at highway speeds.

Does all this changing of tire pressure seem odd? It's the way a road-saving experimental system called central tire inflation works. Originally developed by the Army, the equipment is being tested by U.S. Forest Service officials who say it may revolutionize the way logs are hauled to mills.

Preliminary research conducted by the Forest Service's Equipment Research Development Center indicated that lower-

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Air hoses are attached to each wheel hub with a special rotating valve that prevents air escaping from the system.

ing tire pressure on log trucks resulted in a larger "footprint," giving better traction and a smoother ride while reducing wear of the road's surface.

One of the experiments took place in Oregon's rugged coast range, where seven log trucks were outfitted with a prototype tire-inflation system cobbled together from valves, hoses, and a computer-control box located inside the cab. Air was supplied by the same compressor that powers the truck's brakes.

Normally, trucks operate with 90 to 110 psi of pressure in each tire, but the Oregon experiment showed that much lower pressures worked better off road. "We figured we saved a total of \$28,000 in road maintenance," says Harry Rickard, zone engineer for the Mapleton ranger district of the Siuslaw National Forest. "The experiment far exceeded our expectations. It's going to work well for anyone who needs to use vehicles off road." The research, he adds, has generated considerable interest among tire manufacturers and state highway departments. —Bill Calder

On base in space [Continued from page 99]

The station will have four of these nodes. Laboratory and habitation modules and U.S. logistics modules will be attached to them. So will additional laboratory modules being built in Europe and Japan.

Visitors to space

International cooperation is a key to the U.S. space station's ultimate success. Foreign crew members will often be aboard—and when they're not, U.S. scientists will have the use of their laboratories.

Forward nodes will be mated at the opposite ends of the large U.S. modules on the tenth assembly mission, with windowed cupolas attached to the top of one node and the bottom of the other. The cupolas will give crew members panoramic views of the station, sky, and Earth. Midway through this mission, astronauts also will move a pair of shuttle docking tunnels to their permanent positions on the forward nodes. From vantage points in the cupolas crew members then will be able to guide an incoming shuttle to its berth, perhaps even using a remote manipulator arm to help nudge it into place. The arm also will be used to offload cargo.

Moving through the node, I finally reached the habitation module and saw how crews will live during the long months in orbit. Comfort is a major concern. Again, everything comes in standard-sized replaceable racks—the kitchen with twin microwave-convection ovens, a refrigerator, clothes- and dishwashers, food-storage cupboards, toilet and shower units, and even the individual quarters of the crew, or bedrooms.

Video chats

A combination entertainment and communications console fits into one rack. Here the crew will be able to watch video movies, listen to music, or have occasional two-way video chats with family members visiting the Mission Control Center in Houston. Nearby, an innovative folding conference table could be deployed from the wall, so the crew could eat together, hold meetings, or simply relax with a book. Behind the table, I saw a large port that will give a clear view of Earth passing below.

That was when I knew something was wrong. In the laboratory module, a small viewing port in the floor looked at Earth. How could Earth be seen from both angles? My guide explained: When the habitation module is installed, it will be turned 90 degrees to allow viewing of Earth through a wall port rather than through the floor. Crew members will simply twist their

bodies as they pass through the connecting nodes to maintain the proper up-down orientation in each module. That's something we couldn't do in normal gravity.

Space-station residents also have to make adjustments, both mental and physical, in using their individual quarters. Each bedroom will be built into a standard 42-inch-wide rack, with walls that slide out about 10 inches into the aisle. Bedrooms will be grouped in two sets of four around the perimeter of the module; two people will sleep in the ceiling and two more will be in the floor.

Cramped quarters

To give crew members extra room, Boeing has proposed that bedrooms be expanded to 63 inches wide. Three racks would hold two bedrooms. NASA is studying the option. In addition, NASA requires that the wall between bedrooms be removable. Future crews may include married couples, and their quarters would be combined by pulling out a wall.

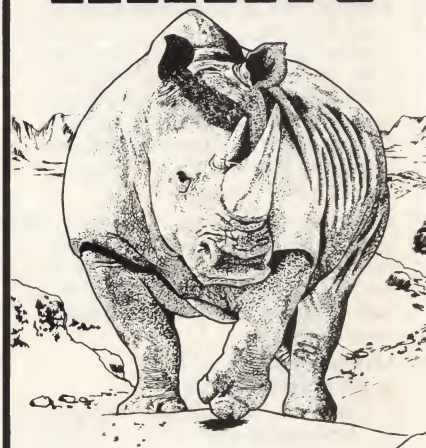
Even so, quarters are cramped. A loose-fitting sleeping bag hangs from a wall; there's no need for a traditional bed in zero-gravity. Drawers, cabinets, and storage bins are all within arm's reach, and a mini-entertainment and communications unit with its own small video screen is equally close. While standing in one of the little compartments, a stray thought crossed my mind: "This is where they keep the canned astronauts." But then the realities of zero g dawned anew. When you're floating in midair, a small room is bigger than it seems.

With the space station's architecture settled and design work now far along on most of its components, scientists from universities and private companies are beginning to plan how they will use it. They'll begin submitting proposals to NASA in the next few years. Time aboard the station will be scheduled much as astronomers compete for observing time on the nation's major telescopes.

"The term 'space station' doesn't convey what this truly is," said Bob Thompson, a former NASA pioneer who made important contributions to Apollo and other manned space missions and is now vice president of McDonnell Douglas's space station division. "We're opening a national laboratory in space, and our thinking should be visionary."

"We're adding a new dimension in life sciences, astronomy, understanding our Earth, creating new materials. The knowledge that will come from that facility will bring progress we can't even imagine."

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Micromachine magic

[Continued from page 92]

"and make a surgical tool to cut through a nerve—just a nerve and nothing else."

Then too you could develop dot-size cleaning robots to remove barnacles, scour out pipes and sewers, and polish away corrosion in hostile environments. You'd make them in quantity, cheap as watch transistors, with no worry of maintenance, theft, or repair. They'd work together like army ants. And sending a million microrobots to Mars might be cheaper than sending just one soil sampler. If 100,000 IC chips can be turned out in one batch, so could 100,000 micromachines.

Ultimately, untethered microrobots could float through the body—thousands of them from one injection—cleaning out deposits, scouring tubing, sensing cancer cells by their defective genetic code, and then puréeing them.

At least this is what K. Eric Drexler, research affiliate at MIT's Artificial Intelligence Laboratory and a visiting scholar at Stanford, sees in his vision of a micromachine branch he calls "nanotechnology." These "cell-repair machines," he says—built of protein through genetic engineering—will identify and destroy bacteria, viruses, cancer cells, parasites, and blood clots.

Building with atoms

He also sees microscopic "assemblers" constructing other machines atom by atom—"man's ultimate technological breakthrough," as he says rather grandly. It's an advance, he says, that is not just possible, but inevitable.

The most balanced long-term view, perhaps, is the kind of skepticism of Berkeley's Muller, who points out that absolutely nobody foresaw the biggest use of computers: word processing. "We who came through that revolution look at this one and say, 'Oh yes, here are some devices we can make.' What we don't realize is that a whole lot of new people, with new ideas, just got on the bus. And they're thinking in terms of millions of dirt-cheap devices all doing the same thing like the Radio City Rockettes. They're thinking about interfacing with nature in new ways, about thermodynamics, about control of mechanical elements at dimensions that are commensurate with the mean-free paths of molecules. They're talking about influencing phenomena that we hardly know exist. Now that's revolutionary. That's real excitement."

And then, on the other hand, there's the nightmare side: a half million flying saws the size of chiggers spreading through the enemy's quarters, homing in on anything warm. **P 3**

Magna fridge

[Continued from page 93]

atures [July '87, April '88, "Science Newsfront," June '88], magnetic refrigerators may eventually become economical for a variety of cooling tasks.

"The underlying technology has been around for decades, used for scientific low-temperature research," Price explains. But until recently scientists had not figured out how to keep a thermo-magnetic material moving through alternating hot and cold cycles so it would provide continuous refrigeration. The Hughes team headed by Dr. Frithjof Mastrup, working under a U.S. Air Force contract, solved that problem with its wheel design.

Attached to the wheel's rim are thin tiles of the magnetic material (see drawing). The wheel spins, and the crystals pass in and out of a powerful field generated by superconducting magnets bathed in frigid liquid helium. As the crystals are magnetized and demagnetized they warm helium passing through one heat exchanger and cool helium in a second loop.

Hughes engineers tested the experimental refrigerator from August 1987 to January 1988, and were refining the design when the contract was canceled in late 1988. In one test the refrigerator ran for three hours. "The only limiting factor is the liquid helium for cooling the superconducting magnets," says Price. "It eventually runs out." A space-borne refrigerator would include a recirculation system for the helium, allowing up to 10 continuous years of operation before normal leakage depletes the supply.

Spinning in space

One refrigerator was delivered to the Air Force later in February. It'll be used for research on sensors being designed for the Strategic Defense Initiative ("Star Wars") program. "For a space system, a refrigerator needs to be efficient, lightweight, and not draw much power," Price tells me. "A gas-cycle refrigerator working over the same temperature span is power intensive and heavy."

Magnetic refrigerators could also be used to cool the superconducting magnets of magnetically levitated trains. And the computer industry may need refrigerators for super-fast machines that are required to operate at extremely low temperatures.

Meanwhile, the advent of superconductors that function at higher temperatures means that the Hughes refrigerator's superconducting magnets may not always have to be cooled by expensive liquid helium. Eliminating the helium will not only reduce the complexity of the refrigerator, but may eventually make the technology competitive with gas refrigerators. **P 3**

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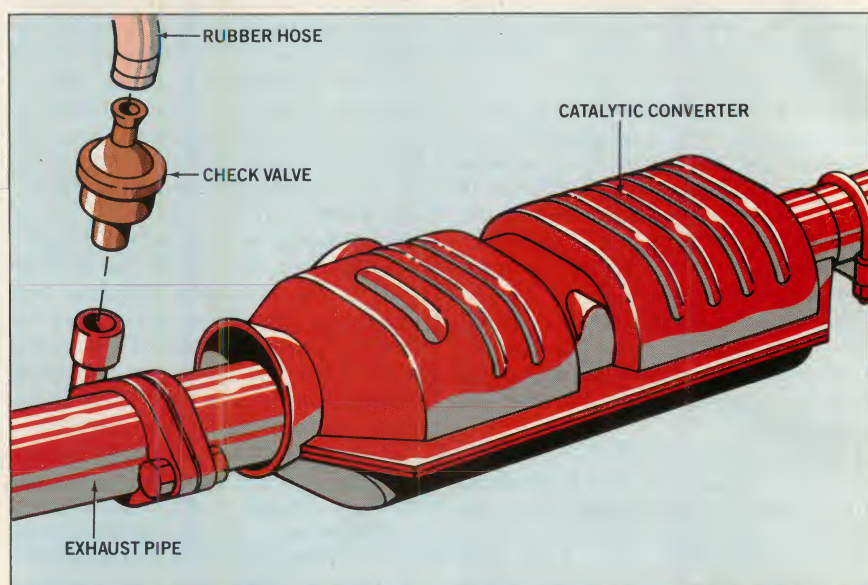
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By STEVE MERCALDO

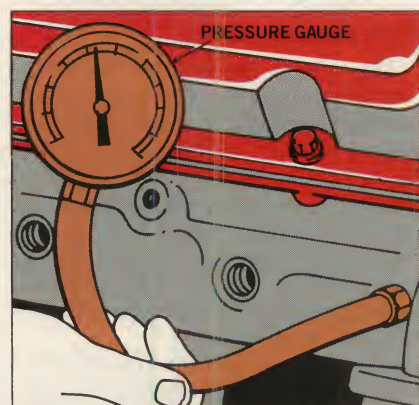
DRAWINGS BY RUSSELL VON SAUERS



Annoying rattles in the exhaust system

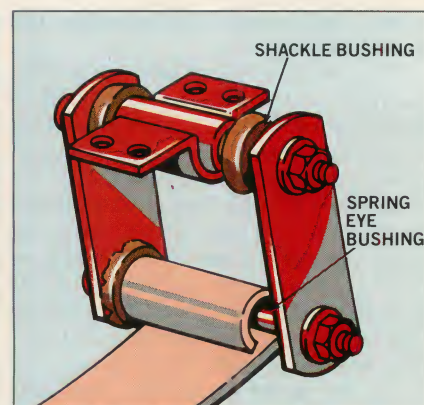
If there is an annoying rattling noise coming from your car's exhaust system and there are no obvious problems, check the air pump and its plumbing. There is an in-line check valve on the hose between the air pump and the catalytic converter that will rattle if broken when the engine is at operat-

ing temperature. To check, start the car and allow it to warm up. While a helper revs the engine, listen near the valve for a rattling noise. Try pinching off the rubber hose with pliers to block the airflow to the check valve. If the rattle stops, the valve is defective and needs to be replaced.



Compression cleaner

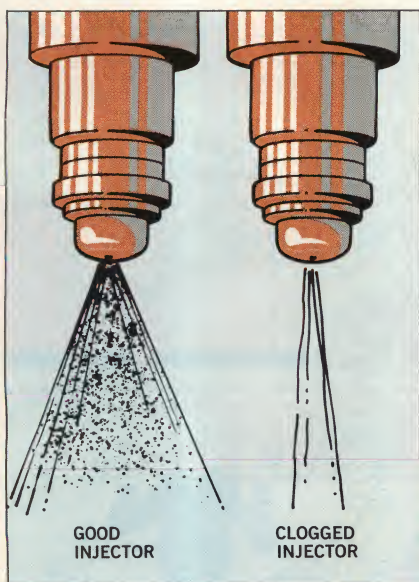
Before performing a compression test, it is important to clear out any loose carbon from the cylinder. Stray particles can lodge between the valve face and the seat, giving a false low reading. Before connecting the pressure gauge, loosen the spark plug one turn, start the engine, and accelerate to 2,000 rpm to scavenge the cylinder.



Leaf bushings

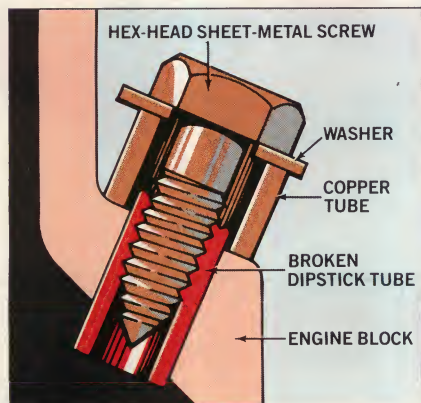
A banging or groaning noise coming from your car's leaf springs when you go over bumps could result from worn or missing support bushings. Check for tired bushings by jacking up the vehicle and visually inspecting the spring eye and shackle bushings for damage or wear. Any that allows metal-to-metal contact must be replaced.

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Injector checkup

To check for clogged fuel injectors on a throttle-body fuel-injection system, connect a timing light to the engine. With the engine at idle speed, point the timing light down the throttle body, looking at each injector's fuel-spray pattern. The proper pattern is an even dispersal of fuel in a fine, steady mist.



Dipstick tube remover

To remove a broken dipstick tube from the engine block, insert a hex-head sheet-metal screw with a washer and a piece of copper tubing slightly wider than the broken tube, as shown in the drawing. Tighten the screw into the broken dipstick tube until the screw starts to thread onto the tube, then pull on the assembly to remove the tube.

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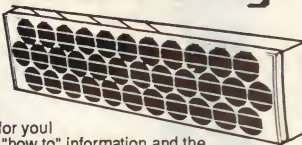
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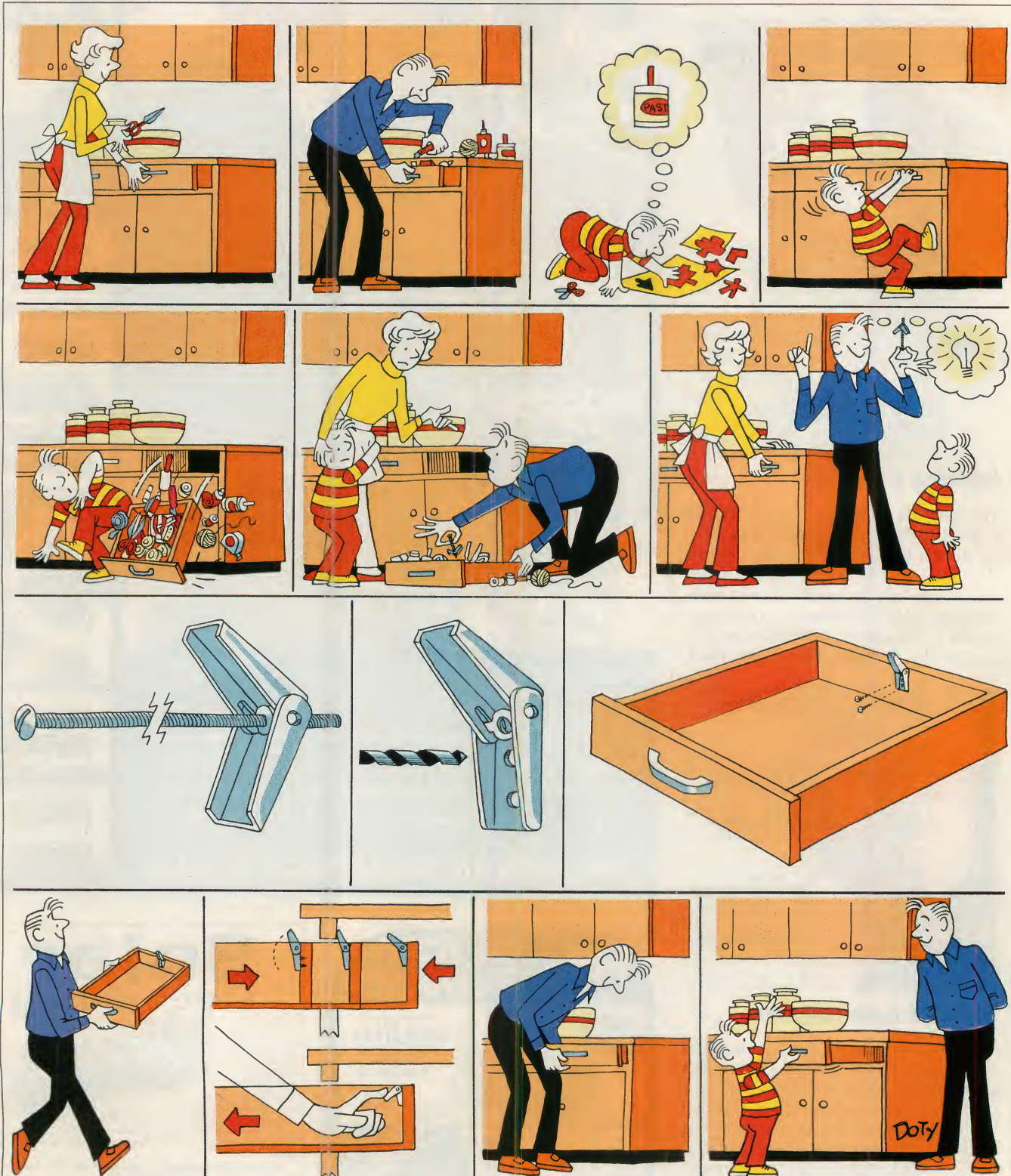
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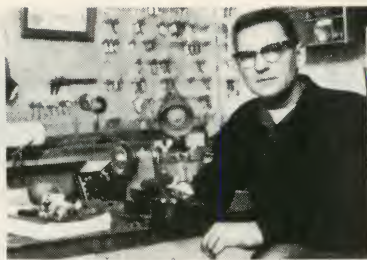
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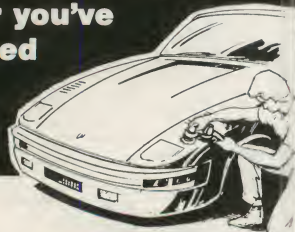
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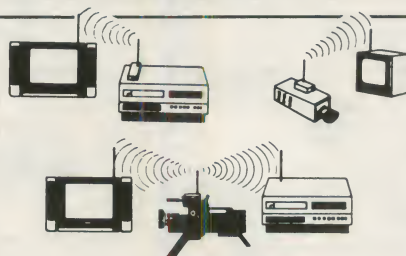
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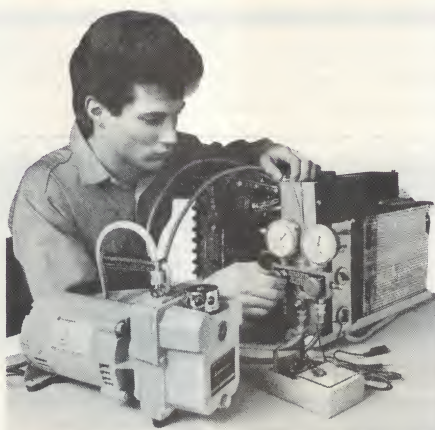
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Say, Smokey [Continued from page 109]

ture. Of course, I hope we'll eventually find a new way to move ourselves around without burning hydrocarbons, but it's too far off to count on. I don't see diesel as having a prayer; it's too dirty, and there's no effective cure in sight. Visit a city with a 25-percent diesel-vehicle population. Your eyes water and everything smells of diesel; it's just impossible.

We are going to run out of oil someday. But even if we had enough oil to power us on into infinity, you couldn't keep burning it at the rate we do because of what it's doing to the atmosphere of this Earth. You know we've got plenty of coal, but in reality it might as well be on the moon. We simply can't use it on a mass scale because of the damage it does to the environment.

What right do we have to simply use up all of the resources and decide that we could care less about people 100 years from now? But that's really what a lot of idiots are saying: *I don't give a damn what will happen in the year 2100. By then they'll come up with some new source of energy that's clean and renewable.* You can't be sure of that. Hell, 100 years is only a few pages in the history book.

... the social responsibility of auto makers

Whether they want the responsibility or not, General Motors, Ford, Chrysler, Toyota and all the rest are charged with furnishing safe, economical, and environmentally viable transportation. They are the people who should know when we are going to run out of oil. They should know how much energy should be put into the car, and how much energy you can get back at recycling time.

The car companies are the ones who should be saying we're going to have to start making smaller cars because we don't see anything on the horizon yet that's going to replace hydrocarbon fuels, and we know that these fuels will be out of the picture within 100 years or so. And they should then educate all of us about this.

To conserve energy you've got to make a car that will last 30 years. It's doable—has been doable for 50 years. There are a lot of negatives to this as far as the car companies are concerned, but car companies don't have to devote all of their energy to just selling automobiles. They could be doing other things too. Built-in obsolescence is a

terrible thing; it's time for them to stop.

We have to say if you're going to use quite a few million Btu to create that car, we want it to run for 30 years. It takes so many Btu to make a car, so many Btu to run and maintain it over its life cycle. Finally, I want to know how many Btu I can get back through recycling. It's like having an energy bank account, where you think hard before you make a withdrawal.

... the workings of big auto companies

The system in Detroit works like this: Say you're my boss. That means you were the guy who designed whatever we're working on right now: engines, suspension, whatever. If I take what you did two or three years ago, and I truly improve on it—without any major breakthrough coming along—I just proved that you didn't know what you were doing. But you're the boss. Now how in the hell does that work?

Today we're told that everything is new and better. But the thing that runs through my mind is, if it's new and better this year because they fixed it, does that mean it was junk last year?

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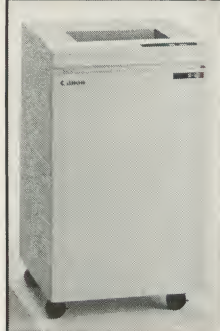
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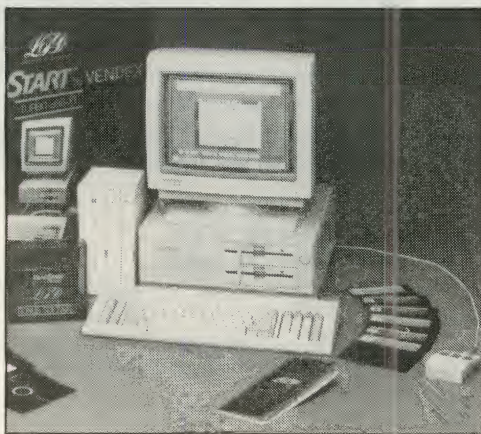
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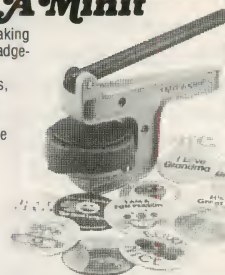
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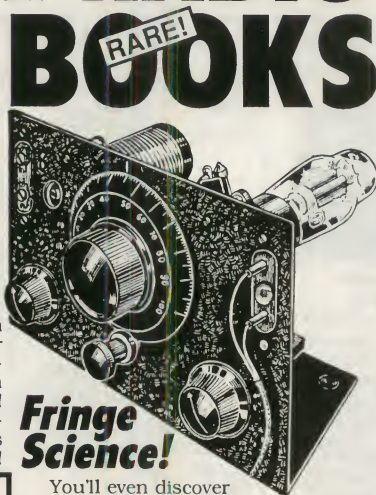
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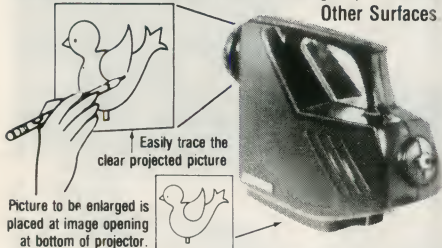
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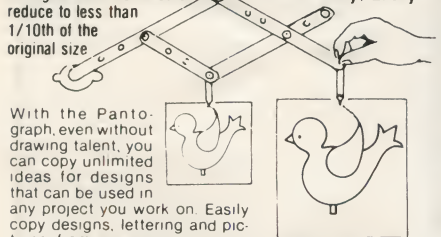


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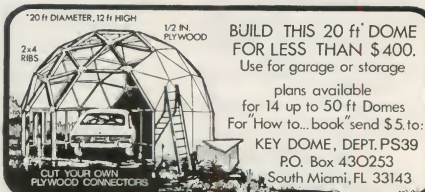
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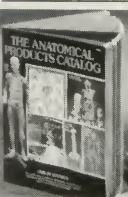
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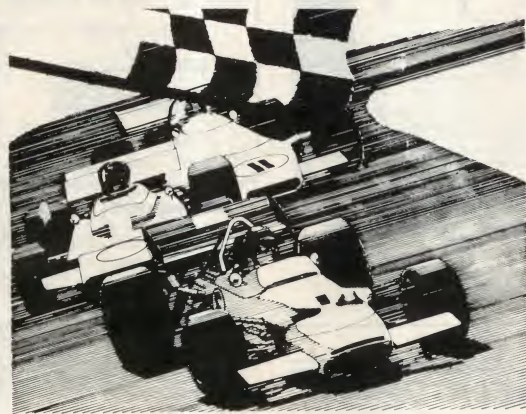
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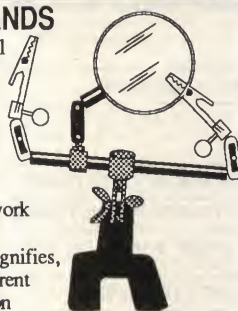


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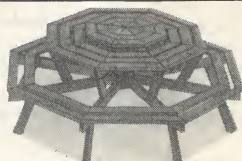


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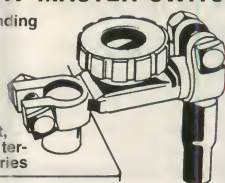
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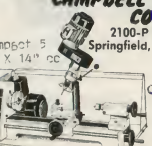
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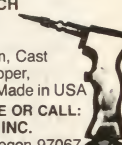
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